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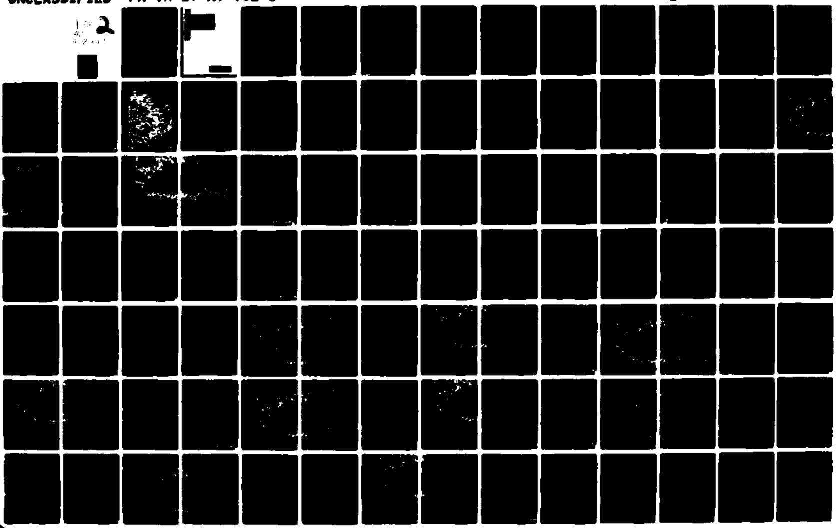

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FN-TR-27-RV-I

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - RALSTON VALLEY, NEVADA

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

15 June 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents results of geotechnical studies which were conducted in southern half of Ralston Valley, Nevada. Included are basin-fill characteristics, construction considerations, geologic setting, soils, terrain, and water.

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FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A2. It contains an evaluation of the suitability of Ralson Valley, Nevada, for siting the MX Land Mobile Advanced ICBM system and presents the geological, geophysical, and soils engineering data upon which the evaluation is based.

This report is included as one of several being prepared to describe Verification studies in the Nevada-Utah region even though these data were gathered during an earlier phase of investigation called Characterization and does not include all facets of a Verification study. Reports on the Characterization studies contained only brief summaries of results, so it was decided to publish details of the investigations and results, in the style of Verification reports, for the two Characterization studies in the Nevada-Utah region.

The Verification studies, which were stated in 1979, are the final phase of a site-selection process which was begun in 1977. The Verification objectives are to define sufficient suitable area for deployment of the MX system and to provide preliminary soils engineering data. Previous phases of the site selection process were Screening, Characterization, and Ranking. In preparing this report, it has been assumed that the reader will be familiar with the previous studies.

Volume I of this report is a synthesis of the data obtained during the study. It contains discussions relative to the horizontal and vertical shelter basing modes. Volume II is a detailed compilation of the data which may be used for independent interpretations or analyses.

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LIST OF DRAWINGS

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LIST OF APPENDICES

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VOLUME II

1.0 INTRODUCTION

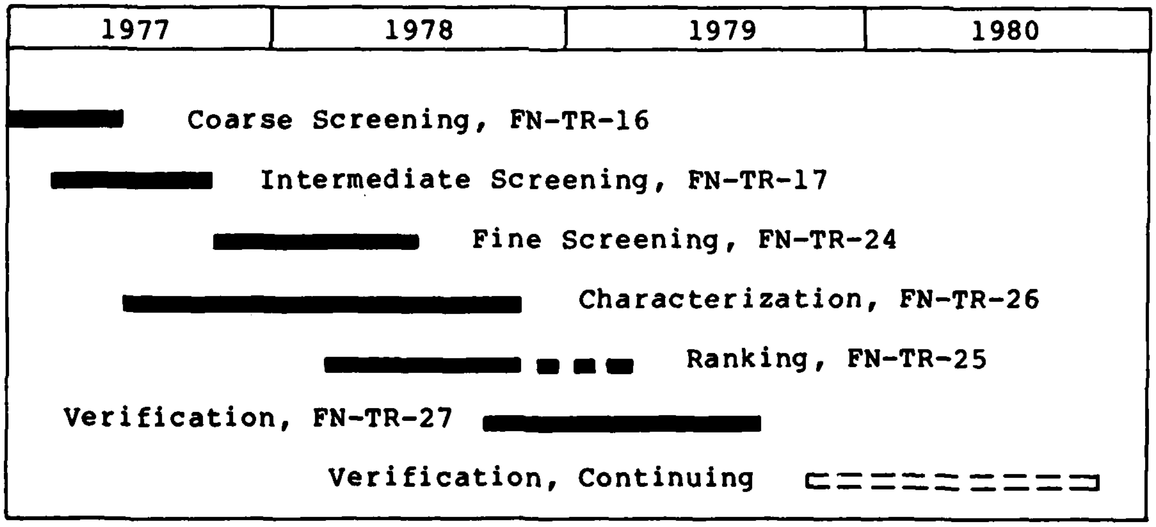
1.1 PURPOSE AND BACKGROUND

This report presents the results of geotechnical studies which were conducted in the southern half of Ralston Valley, Nevada, during the summer of 1977. The work was done as part of Fugro National's Characterization Studies, which were summarized in report FN-TR-26e. This more detailed report follows the format of reports covering Fugro National's Verification Program, even though the Characterization field investigation did not include all the elements of a Verification investigation. The report contains two volumes. This volume is a synthesis of the data. Volume II is a compilation of the data from each activity.

This work is a phase of a site selection process which started in 1977. The objective of the site selection process is to identify and rank geotechnically suitable areas which are sufficiently large for deployment of the Missile-X (MX), an advanced intercontinental ballistic missile system. The phases are called Screening, Characterization, Ranking, and Verification. Screening employed existing information from literature to identify areas which appeared to be suitable for deployment of MX. Both Characterization and Verification programs use field studies. Characterization studies emphasized collection of information to characterize geologic units with respect to construction of the MX basing options. Verification studies also obtain information on construction properties of

the geological units, but special emphasis is given to drawing more reliable useable area boundaries than those drawn during the Screening studies. Table 1-1 summarizes the investigative techniques being employed during Verification studies and points out those which were not used in Ralston Valley. Another difference between the two programs is that, for Verification, more of the investigations were done near the valley margins than in the Characterization studies.

The site selection schedule is shown in the following diagram, which also identifies the Fugro National technical report for each element in the process. As shown, the Verification Program



is continuing in 1980. The valleys for which reports have been issued on the Verification studies are shown in Figure 1-1. This report is included because the detail of content is at the same level as for Verification reports, even though the emphasis of the field investigation was different.

OBJECTIVES → VERIFICATION OF INTERMEDIATE/FINE S

DATA FOR EVALUATIONS → TERRAIN PARAMETERS | 50'/150' DEPTH TO ROCK

FIELD TECHNIQUES AND APPLICATIONS →

TERRAIN PARAMETERS

Geologic mapping

- Identification and limits of areas with slopes greater than 10% grade
- Identification and limits of areas with high incidence of 10% slopes (rolling terrain)

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of r
- Subsurface limits o from topographic an geologic interpreta
- Geomorphic expressi erosion history

Seismic refraction s

- Subsurface projecti rock limits
- Delineation of rock high (>>7000 fps) v velocities

Borings

- Occurrence of rock

Gravity surveys (

- Overall basin sha relationships
- Range-bounding fa

Existing data

- Published literat

RMEDIATE/FINE SCREENING SUITABLE AREA

CHARACTERIST

50'/150' DEPTH TO ROCK	50'/150' DEPTH TO GROUND WATER	EXTENT AND CHARACTERISTICS OF SOILS	GEOPHYSICAL PROPERTIES

50'/150' DEPTH TO ROCK

logic mapping

- urface limits of rock
- ubsurface limits of rock from topographic and eologic interpretation
- eomorphic expression and rosion history

mic refraction surveys

- ubsurface projection of ock limits
- elineation of rock from igh (>>7000 fps) p-wave elocities

ngs

- ccurrence of rock

ity surveys (DMA)

- verall basin shape and elationships
- nge-bounding faults

ting data

- blished literature

50'/150' DEPTH TO GROUND WATER

Existing data

- Available well records and interpretation

Borings

- Occurrence of ground water

Electrical resistivity/ seismic refraction surveys

Provide supplemental data to support presence or absence of ground water

Geologic mapping

- Obtain water depths from wells encountered in field

EXTENT AND CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches, test pits*, and surficial samples*

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soils
- Samples for laboratory testing

Cone penetrometer tests*

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties - shear strength, compressibility
- Chemical properties

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

RACTERISTICS OF BASIN FILL

RECOMMENDATIONS FOR FUTURE VERIFICATION STUDIES

ROPERTIES

tion surveys

- wave

stivity

ductivity of

oil

ROAD DESIGN DATA

Trenches, test pits*, and Surficial samples*

- Identification of soil types
- In situ soil density and moisture
- Thickness of low strength surficial soil

Cone penetrometer tests

- In situ soil strength
- Thickness of low strength surficial soils

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbbase, or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

Borings

- Subsurface soil types
- Presence of cobbles and boulders
- In situ density of subsurface soils
- Stability of vertical walls

Trenches and test pits*

- Subsurface soil types
- Subsurface soil density and cementation
- Stability of vertical walls
- Thickness of low strength surficial soils
- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of soil types

Seismic refraction surveys

- Excavatability

* There were no cone penetrometer, testpits, surficial samples nor electrical resistivity measurements made in Ralston Valley.

FIELD TECHNIQUES VERIFICATION STUDIES	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - SAMSO	TABLE 1-1

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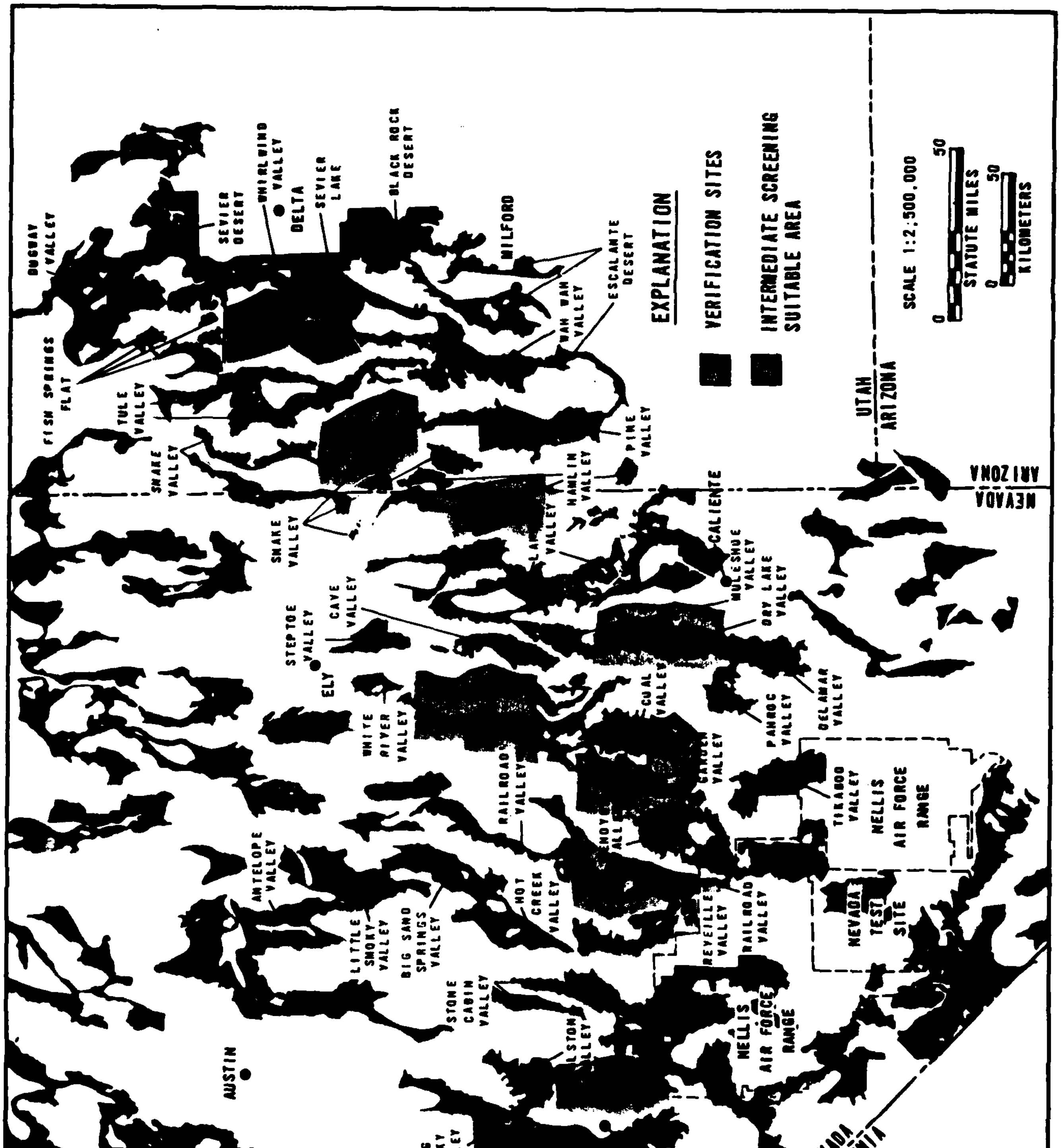

VERIFICATION REPORTS TO DATE
NEVADA–UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 1-1

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1.2 VERIFICATION OBJECTIVES

The Verification studies have two major objectives:

1. Verify and refine suitable area boundaries for horizontal and vertical shelter basing modes.
2. Provide preliminary physical and engineering characteristics of the soils.

The data in this report are more pertinent to objective 2 than objective 1.

1.3 SCOPE OF STUDY

The field work in Ralston Valley was done in August 1977. Table 1-2 lists the types and number of field activities that were performed in Ralston Valley. The techniques of investigation are discussed in the appendix.

Access was arranged through the Tonopah Resource Area Office of the Battle Mountain, Nevada, district office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. Archeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few instances where a potential environmental or archeological disturbance was identified.

1.4 DISCUSSION OF ANALYSIS TECHNIQUES

1.4.1 Determination of Suitable Area

The number of field activities performed during these investigations is small relative to the area being studied. The reader should be aware of the limitations of the investigations and

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	58
Shallow refraction	15
Down Hole Velocity	3
Deep Refraction	2

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	120
Specific gravity	16
Sieve analysis	142
Hydrometer	63
Atterberg limits	31
Consolidation	7
Unconfined compression	12
Triaxial compression	21
Direct shear	18
Compaction	4
CBR	3
Chemical analysis	8

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
4	300 (91)
9	75-100 (23-30)
2	30 (9)
NUMBER OF TRENCHES	**NOMINAL DEPTH FEET (METERS)**
8	18 (5)

SCOPE OF ACTIVITIES
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 1-2

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must recognize that there may be additional revisions regarding the suitability of areas as the studies continue. Maps showing interpretations of depth to rock, depth to water, and terrain conditions are included in Section 3.0.

a. Depth to rock: For Verification studies, 50- and 150-foot (15- to 46-m) depth to rock contours are based on geologic, geophysical, and boring data. In Ralston Valley, the borings and geophysical lines are generally several miles from outcrops. Therefore the locations of the contours are based primarily on geologic interpretation. The interpretation considers the presence or absence of range-bounding faults, bedding plane attitudes, topographic slopes, evidence of erosional features such as pediments, and the presence or absence of young volcanic rocks.

b. Depth to water: The depth to water map is a literature based evaluation using existing wells. Ground water at a depth of less than 150 feet is encountered only in a local area northwest of Thunder Mountain. Consequently, the depth to water appears to have no major influence on the final suitable area calculated for Ralston Valley.

c. Terrain: During Screening Studies, areas were excluded because of unsuitable terrain. The major exclusion criterion was a maximum permissible grade of ten percent. In many of the areas studied, detailed topographic maps have not been made, and the available maps do not show topographic conditions with sufficient detail to make an accurate evaluation of terrain suitability.

The best available topographic maps of Ralston Valley are at a scale of 1:62,500. In addition to these maps, 1:60,000 scale black and white aerial photographs, and field observations were used as the basis for interpreting terrain conditions.

1.4.2 Determination of Basin-Fill Characteristics

The primary objective of Characterization studies was to provide preliminary physical and engineering properties of the basin-fill materials. These data will be used for preliminary engineering design studies, will assist in planning future site-specific studies, and will be used by other MX participants.

The investigations of engineering properties were designed primarily to obtain information needed for construction activities. For Verification studies particular emphasis has been placed on the surficial soil conditions as related to road construction, a major cost item. However, during Characterization, only limited data were acquired on surficial soil characteristics since a hardened trench was the prime basing mode at that time. Major emphasis was placed on soil conditions in the upper 20 feet (6 m) since this would be the approximate depth of excavation for the trench (as well as the horizontal shelter basing mode). Limited data were obtained from borings drilled to a depth of 160 feet (49 m) (and beyond), which is the depth of interest for the vertical shelter basing mode. The length of the seismic refraction lines was also chosen to obtain information to 150-foot (46-m) depth or beyond.

The geologic map showing the distribution of surficial soils is based on the interpretation of aerial photos, field mapping, and information from trenches.

Data obtained from trenches, borings, seismic refraction lines, and laboratory tests were used to estimate soil properties to a a depth of 20 feet (6 m). The data are limited to that obtained from eight trenches and 15 borings. There may be soil conditions that were not encountered by these 23 data points. Thus, the range of properties presented in the report is subject to revision.

The soil parameters between a depth of 20 and 160 feet (6 and 49 m) are based on data obtained from only 15 borings. The spacing between borings ranged from 3 to 6 miles (5 to 10 km). Thus the data presented may not be representative of the entire valley.

2.0 RESULTS AND CONCLUSIONS

2.1 SUITABLE AREA

The results of the suitable area interpretation are shown in Drawing 2-1 and listed in Table 2-1. The excluded areas are based on depth to rock and water, and terrain conditions (Appendix A2.0). The area interpreted to be suitable for the horizontal basing mode is 225 square miles (583 km^2). Suitable area is reduced to 195 square miles (505 km^2) for the vertical shelter basing mode.

The total area of basin-fill materials in Ralston Valley, excluding rock outcrops, is approximately 290 square miles (751 km^2). Geotechnical constraints (terrain, depth to rock and/or water) exclude 23 percent of this area for the horizontal shelter basing mode. The exclusion is increased to 33 percent for the vertical shelter basing mode.

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in the valley. More detailed information is presented in Sections 3.3 and 3.4.

2.2.1 Surficial Soils

Coarse-grained soils are the predominant surficial soils, covering approximately 90 to 95 percent of the area. They range from gravels with little fines to sands with appreciable amounts of gravel and/or fines. The fine-grained soils are generally

VERIFICATION VALLEY	STATE	AREA MI² (KM²)*		
		BEGINNING AREA	SUITABLE AREA	
			HORIZONTAL	VERTICAL
RALSTON	NEVADA	290 (751)	225 (583)	195 (505)

EXCLUSIONS	AREA MI² (KM²)	PERCENT REDUCTION**
< 50 FEET (15M) TO ROCK	60 (155)	21
< 150 FEET (46M) TO ROCK	87 (225)	30
< 50 FEET (15M) TO WATER	3 (8)	1
< 150 FEET (46M) TO WATER	6 (16)	2
TERRAIN	2 (5)	1

*BEGINNING AREA COMPOSED OF BASIN-FILL MATERIALS EXCLUDING ALL ROCK OUTCROPS ALL LARGE SQUARE MILE AREAS ARE ROUNDED OFF TO NEAREST FIVE SQUARE MILE INCREMENT. METRIC CONVERSIONS ARE ROUNDED OFF TO NEAREST ONE SQUARE KILOMETER INCREMENT.

**PERCENT REDUCTIONS, BASED ON BEGINNING AREA, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT. WATER EXCLUSIONS AND ROCK EXCLUSIONS OVERLAP. WATER EXCLUSION PERCENTAGES ARE IN ADDITION TO RESPECTIVE ROCK EXCLUSION PERCENTAGES.

ESTIMATED SUITABLE AREA
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 2-1

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non-plastic silts and clays. They are mainly confined to an active playa in the southern portion of the valley.

2.2.2 Subsurface Soils

Subsurface soils in the valley are predominantly coarse-grained, consisting of sandy gravels, gravelly sands, silty sands, and clayey sands. Fine-grained soils (sandy silts and sandy clays) probably occur in about five to ten percent of the subsurface and are generally associated with buried playa and lacustrine deposits at the southern end of the valley. Variation in areal extent of playas in the geologic past has resulted in local interfingering of coarse and fine-grained deposits in the subsurface near playa margins.

The coarse-grained soils are generally medium dense to dense below 2 to 5 feet (0.6 to 1.5 m), are poorly graded with coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. The fine-grained soils exhibit low plasticity, low to moderate compressibilities, and low to high shear strengths. Variable calcium carbonate cementation exists in the subsurface soils.

2.3 CONSTRUCTION CONSIDERATIONS

Geotechnical factors and conditions pertaining to construction of the MX system in suitable areas are discussed in this section. Both the horizontal shelter and vertical shelter basing modes are considered.

2.3.1 Grading

Mean surficial slopes in the suitable area are approximately one to two percent (range of zero to six percent). About two percent of the suitable area has surface gradients exceeding five percent. Therefore, preconstruction grading will be minimal for most of the valley.

2.3.2 Roads

The predominant coarse-grained surficial soils will generally provide good subgrade support for roads where they are in a dense state. However, most of these soils do not appear to be dense near the surface. The subgrade supporting properties of the granular surficial soils can be improved by mechanical compaction. The vertical extent of low strength surficial soils is not known. Drainage incision depths are generally less than 6 feet (1.8 m) in approximately 95 percent of the area. In the remainder of the valley, the depth of drainage incision ranges from 6 to 20 feet (1.8 to 6.1 m). Therefore, the overall cost of drainage structures for roads will be low.

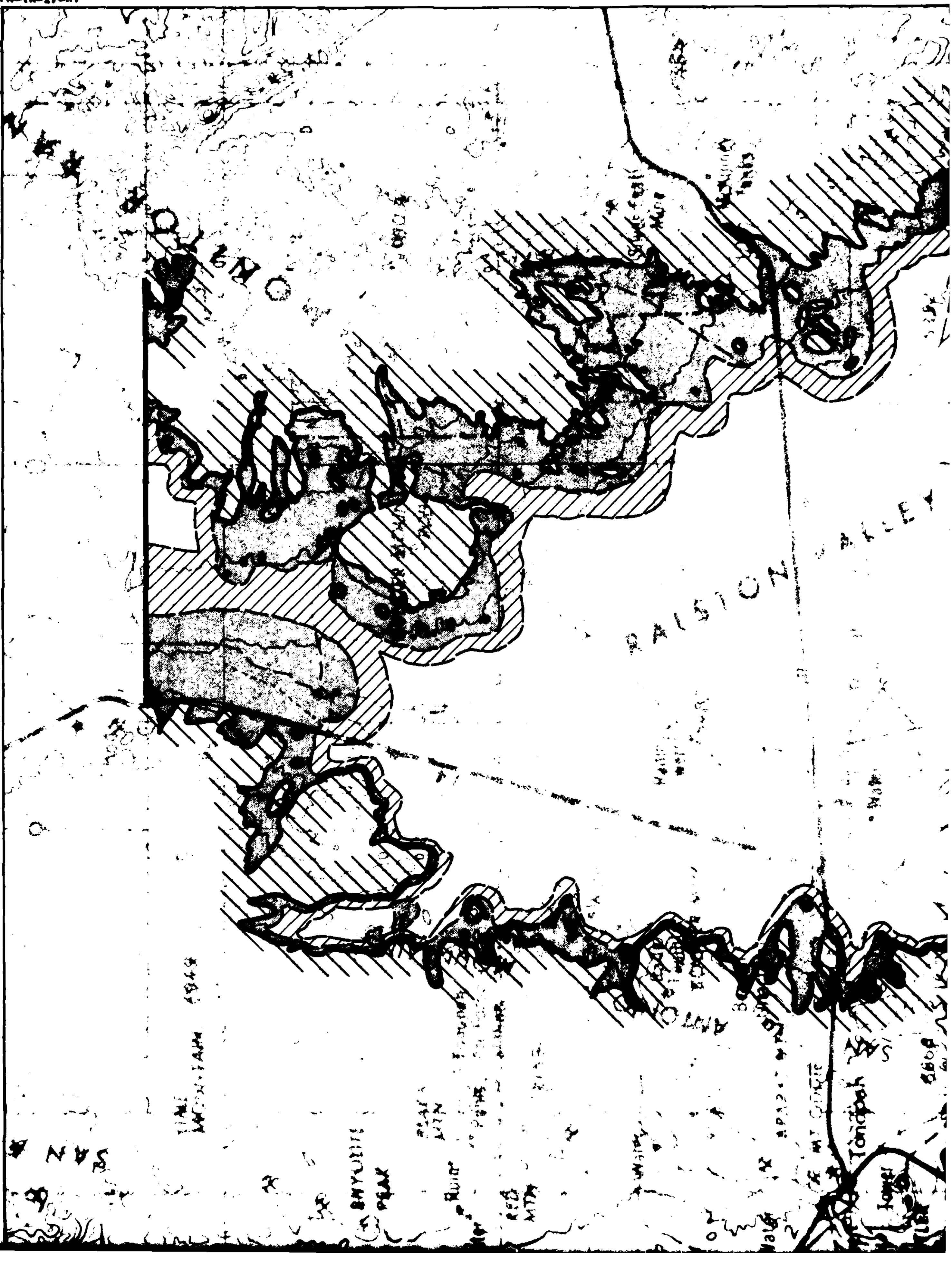
2.3.3 Excavatability and Stability

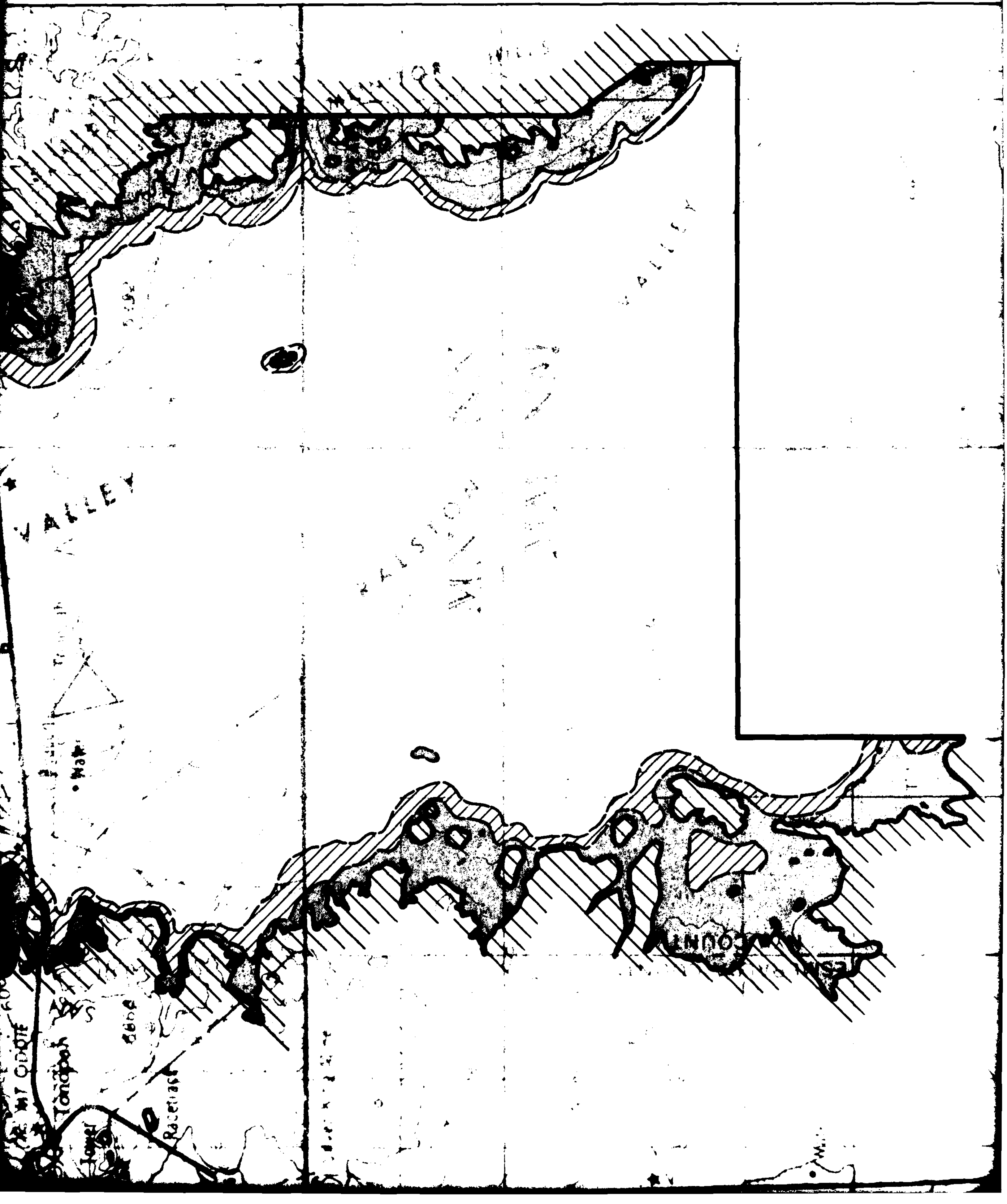
The soils in the construction zone are generally medium dense to very dense and possess variable calcium carbonate cementation. Fine-grained soils occur in less than ten percent of the subsurface.

Horizontal Shelter: Excavation for the horizontal shelter can be done with conventional equipment such as scrapers, backhoes, and dozers. Excavation will be easy in approximately 70 to 80

percent of the area;, however, excavation will be moderately difficult in the remaining area due to presence of cobbles, boulders, and strong calcium carbonate cementation in the subsurface. Difficult excavation generally will be limited to the areas adjacent to the mountain fronts. Results of the soils engineering investigation indicate that excavations for construction of shelters should be cut back to slopes ranging from 3/4:1 to 1 1/2:1 (horizontal:vertical) for stability. The wide variation in slope angle is due to variation in density and shear strength which depend on soil composition and degree of cementation.

Vertical Shelter: Compressional wave velocities in the upper 120 feet (36 m) indicate that large diameter auger drills could be used for vertical shelter excavation. Most excavation will be in granular soils with only intermittent cemented or cohesive soil intervals. Therefore, the vertical walls of these excavations probably will require the use of slurry or other stabilizing techniques.


RALSTON VALLEY
Tonopah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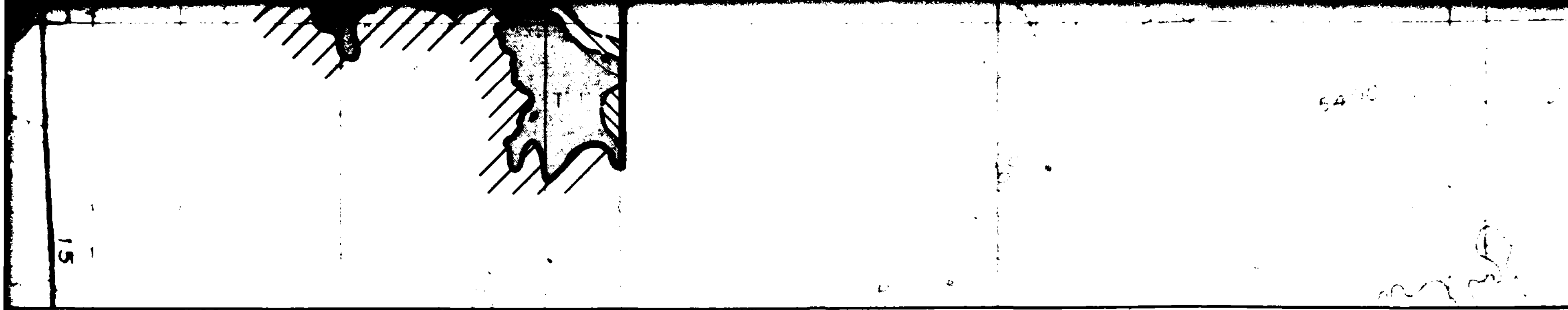


EXPLANATION

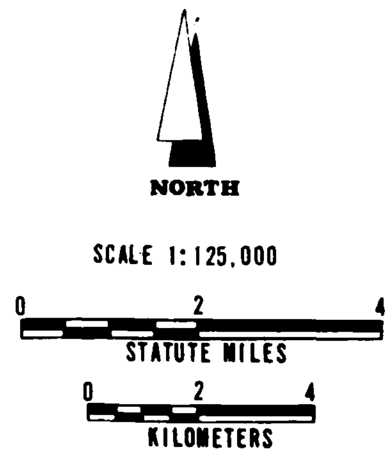
Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

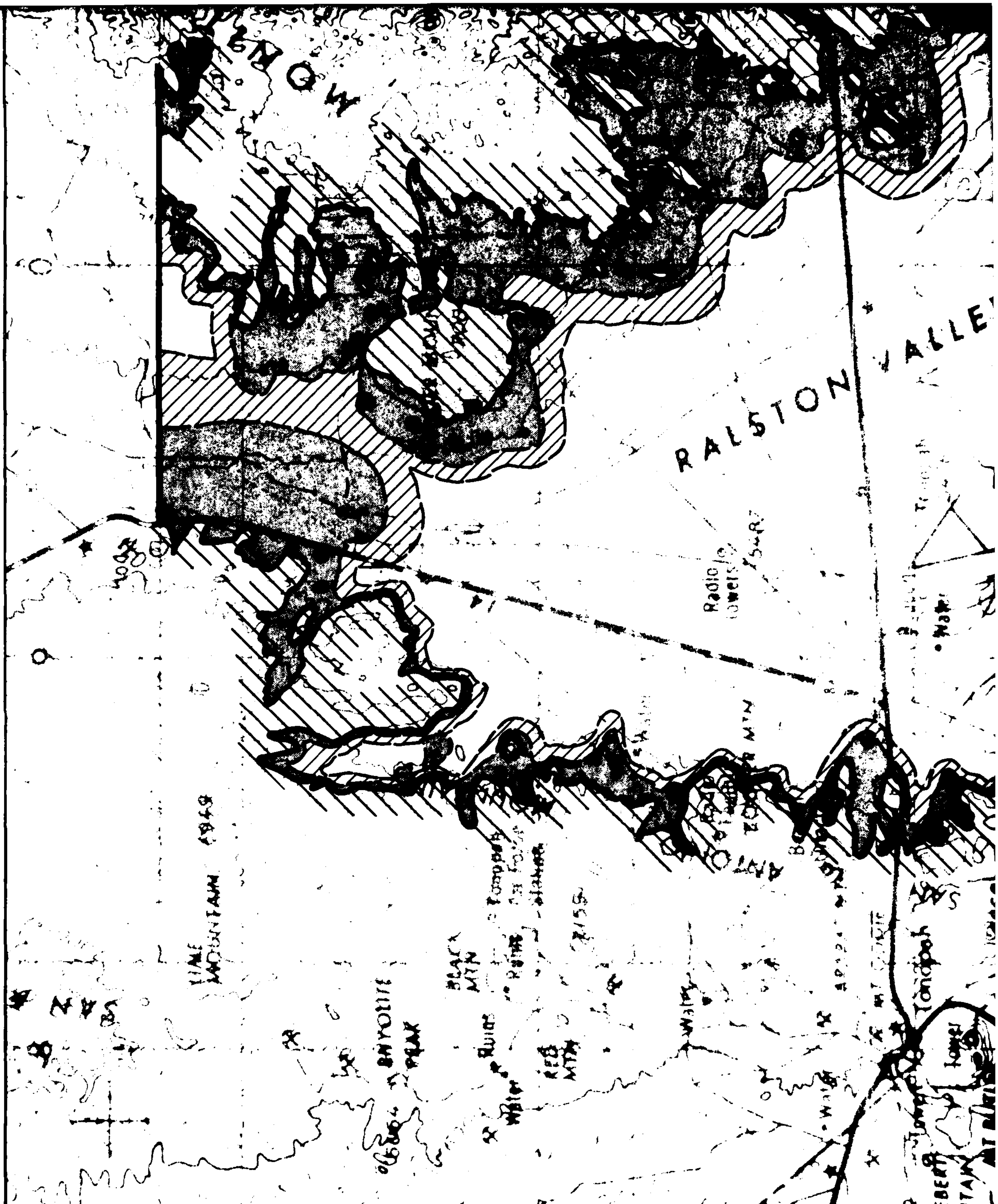
Area suitable for horizontal shelter, but not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topographic terrain, and cultural exclusions (see Appendix A2.0, Table A2-1 for details of exclusion criteria).

Indicates areas of exposed rock.

Contact between rock and basin fill (and northern and southern valley boundaries).

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Crescent dunes
LIME MOUNTAIN
Radio towers
BLACK MTN
RED MTN
Tonopah
SIEBERT MOUNTAIN

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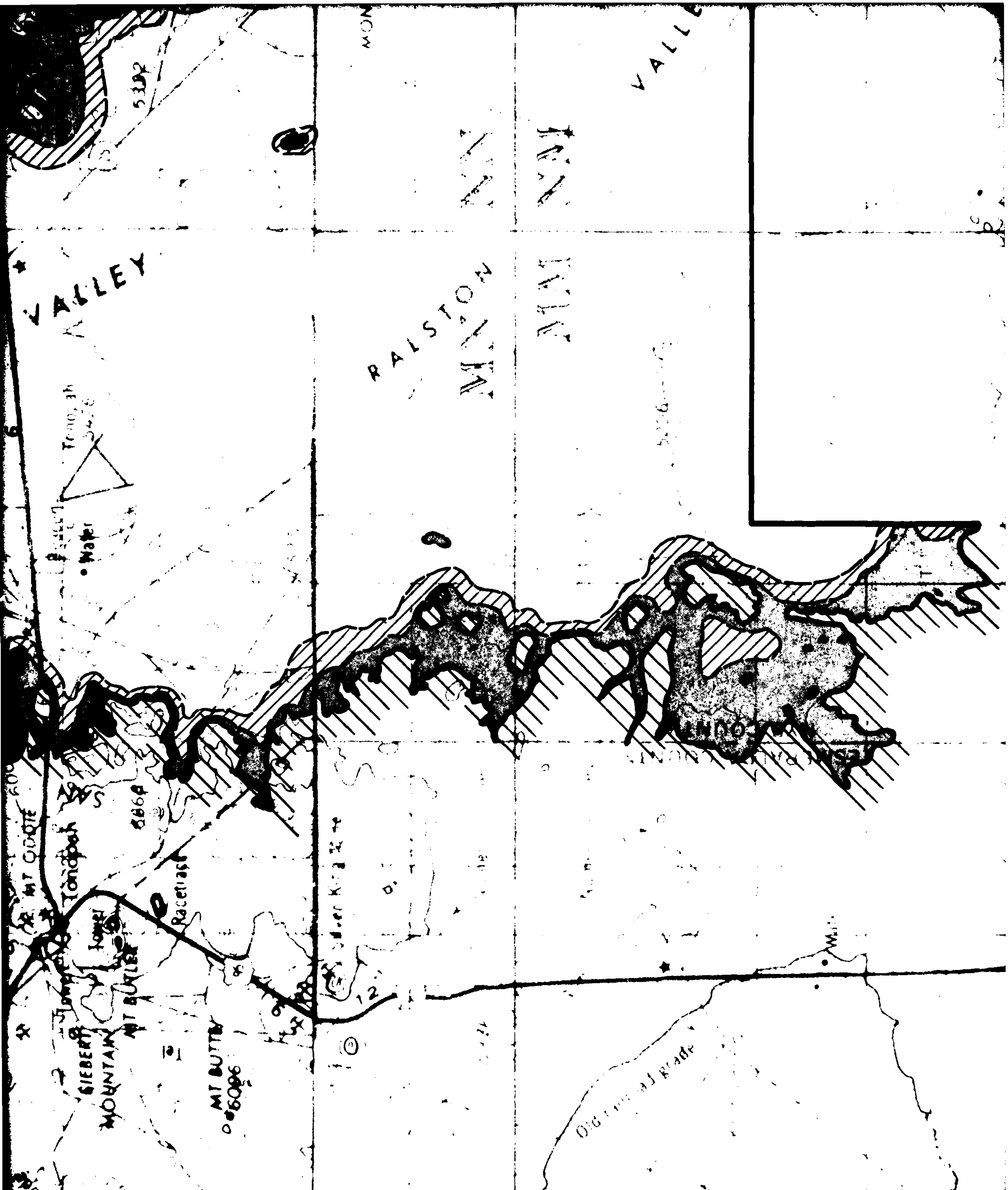
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MT BUTLER
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EXPLANATION

- Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).
- Area suitable for horizontal shelter, but not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).
- Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topographic/terrain, and cultural exclusions (see Appendix A2.0, Table A2-1 for details of exclusion criteria).
- Indicates areas of exposed rock.
- Contact between rock and basin fill (and northern and southern valley boundaries).

SCALE 1:

STATU

KIL

SUITABLE AREA
HORIZONTAL AND VERTICAL SHELTER
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING 2-1

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3.0 GEOTECHNICAL SUMMARY

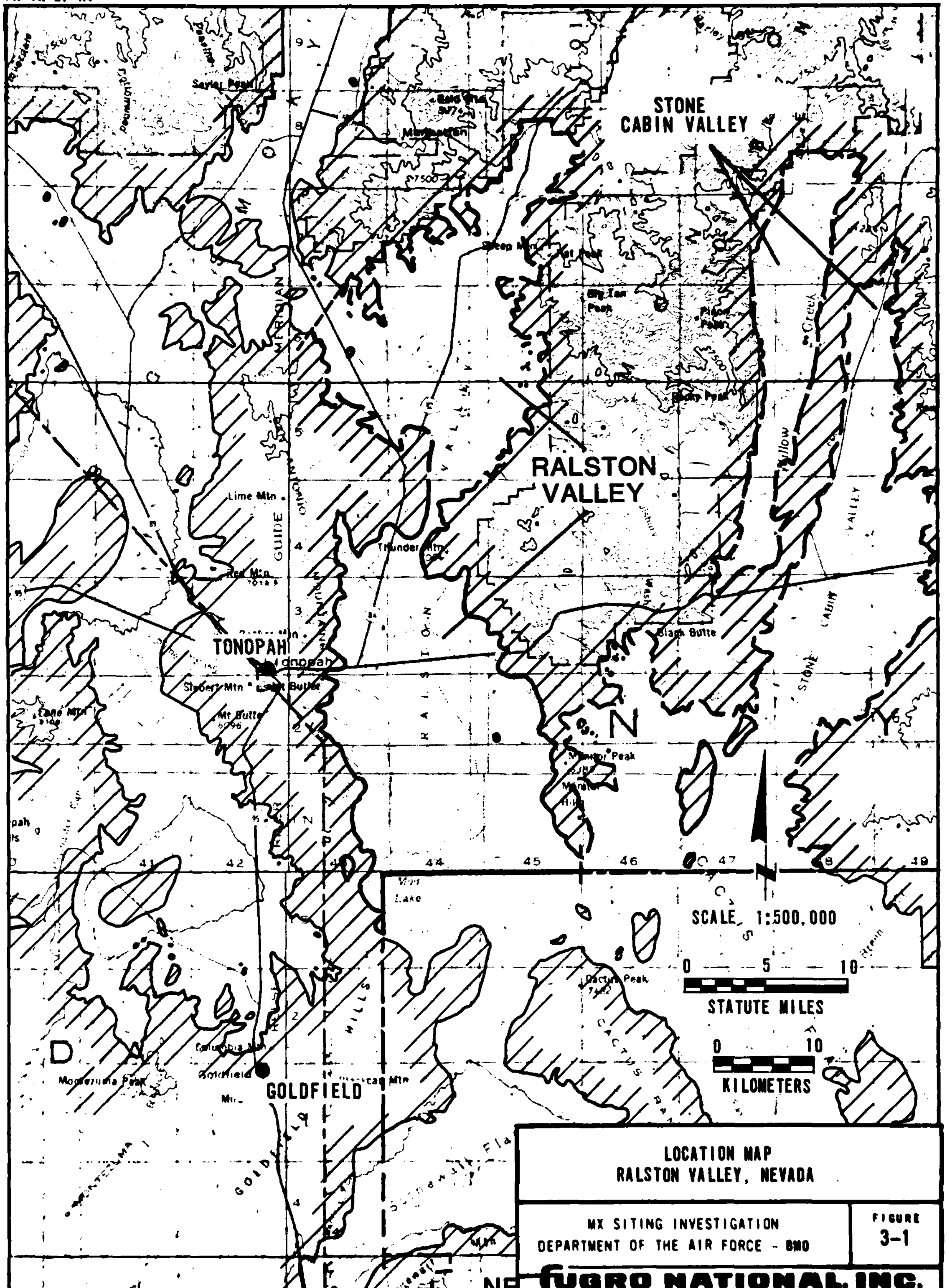
3.1 GEOGRAPHIC SETTING

Ralston Valley is in western Nye County, Nevada (Figure 3-1). The valley is bounded on the west by the San Antonio Mountains and on the east by the Monitor Range and the Monitor Hills. The area investigated is bounded on the north by an extension of Ralston Valley and on the south by the Nellis Air Force Base Bombing and Gunnery Range. The northern boundary of the Ralston Valley study lies along a township division line about 3 miles north of Thunder Mountain. U.S. Highway 6 and State Highway 8A provide paved highway access through the valley, while graded roads and four-wheel drive trails provide access within the valley. The nearest town is Tonopah, Nevada, less than 10 miles (16 km) to the west on U.S. Highway 6.

3.2 GEOLOGIC SETTING

3.2.1 Rock Types

Tertiary volcanic rocks are the dominant rock type exposed in the mountains surrounding Ralston Valley (Stewart and Carlson, 1978; Cornwall, 1972). Of these rocks, welded and nonwelded ash-flow tuff predominates, especially on the eastern side of the valley. Andesite and basalt flows form extensive outcrops on the western side of the valley. Small granitic intrusions of Cretaceous and early Tertiary age occur in the southwest. Small scattered outcrops of Paleozoic limestone, shale, and sandstone are found in the south on both sides of the valley, and probably underlie the Tertiary volcanic rocks.


STONE
CABIN VALLEY
RALSTON
VALLEY
TONOPAH
GOLDFIELD
Lime Mtn
Red Mtn
Thunder Mtn
Black Butte
Monitor Peak
Cactus Peak
Montezuma Peak
Columbia Mtn
Mt Butte
Lone Mtn
Sawtel Peak
Sleep Mtn
Big Ten Peak
GUIDE
MERIDIAN
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SCALE 1:500,000
0
5
10
STATUTE MILES
0
10
KILOMETERS
LOCATION MAP
RALSTON VALLEY, NEVADA
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO
FIGURE
3-1
FUGRO NATIONAL, INC.

3.2.2 Structures

The Ralston Valley area lies east of a zone of disrupted structure which separates the Sierra Nevada Batholith from the Basin and Range province (Bonham and Garside, 1979). This zone roughly corresponds to a prominent zone of topographic disruptions called the Walker Lane (Locke and others, 1979). Walker Lane typically contains major strike slip faults although Ekren and others (1976) and Bonham and Garside (1979) state there is little indication of large scale Tertiary aged faulting of this type in the Ralston Valley area.

Generally, Ralston Valley exhibits typical Basin and Range structure. It is bounded by the north-trending San Antonio Mountains on the west, and by the Monitor Range and Monitor Hills on the east. The dominant fault direction trends to the north, with lesser faulting oriented to the northwest and east-northeast (Stewart and Carlson, 1974). The area of most pronounced faulting is in the San Antonio Mountains where predominantly normal faults offset rocks of early and middle Tertiary age (Stewart and Carlson, 1974). Gravity data indicate that Ralston Valley may be bounded on the east by a normal fault. No bedrock occurs at the surface to the west of this proposed fault, and a pediment is inferred east of it (Fugro National, Inc., 1978, FN-TR-26E). The valley basin is interpreted as a collapsed caldera overlain by younger volcanic rocks and basin-fill deposits (Fugro National, Inc., 1978, FN-TR-26E).

3.2.3 Surficial Geologic Units

Alluvial fans of younger and intermediate relative ages are the predominant surficial geologic units within Ralston Valley (Drawing 3-2). Soil types range from sandy gravel near the mountain fronts to silty sand near the center of the valley. Mixed playa and younger alluvial deposits occupy the central portion of the valley. Major surficial geologic units mapped consist of the following:

- Older Alluvial Fan Deposits (A5o) - This Pleistocene unit is the least extensive alluvial unit in the valley. It occurs adjacent to mountain flanks on the western side of the valley and consists of silty sand with gravel. The unit is in part underlain by shallow rock. Cementation is weak; caliche development varies from Stage II to Stage III. Areal extent is on the order of one percent of the valley.

- Intermediate Alluvial Fan Deposits (A5i) - This Pleistocene unit is a more widespread alluvial unit discontinuously occurring in a fairly narrow band along the base of the mountain ranges on the western and northeastern sides of the valley. The portion of this fan type that abuts the flanks of the ranges is irregularly underlain by shallow volcanic rock. The unit generally occurs as a weak to moderately cemented gravelly sand or silty sand with caliche development varying from Stage II to Stage III. Areal extent is about 15 to 20 percent of the valley.

- Younger Alluvial Fan Deposits (A5y) - Holocene younger alluvium is the most widespread alluvial unit in the valley. It occurs in the valley bottom adjacent to intermediate alluvial fans but does not completely occupy the central portion of the valley. The composition of this fan type varies from gravelly sand with silt to silty or clayey sand with gravel. Cementation varies from none to weak; caliche development varies from none to Stage II. Areal extent is about 25 to 30 percent of the valley.

- Fluvial Deposits (A1) - Holocene fluvial deposits occur primarily along the topographic axis of the valley (located along the western side of the valley). Composition varies from sandy silt to silty sand. Areal extent is less than five percent of the valley.

- Eolian Deposits (A3d, A3s) - Holocene wind-blown deposits occur primarily on the southern and southeastern sides of the valley. Minor deposits of dune sands occur in the northern part of the valley. The unit consists mainly of sand with very minor percentages of gravel and/or silt and clay. Cementation is nonexistent; no caliche development is apparent. Areal extent is less than ten percent of the valley.

- Lacustrine Deposits (A4, A4o) - This unit designation includes Holocene playa deposits and Quaternary-Tertiary older playa and lacustrine deposits. The youngest playa deposits (active playa) occur in the southwestern part of the valley. The older lacustrine deposits occur as narrow linear bar deposits in the southern part of the valley. Playa deposits vary from sandy silt to clay. Lacustrine deposits are silty sand. Areal extent of these units is less than five percent of the valley.

As depicted on Drawing 3-2, various combinations of the above surficial basin-fill deposits exist in the center of the valley. The most widespread combination is of playa and younger alluvial fan deposits (the unit marked A5y/A4f). Other less abundant mixed units also exist (e.g. A3d/A5y, A3s/A5y, etc.). The total areal extent of all such mixed units is approximately 30 to 40 percent of the valley.

3.3 SURFACE SOILS

The geotechnical engineering program in Ralston Valley consisted of only borings and trenches. Therefore, information pertaining to surficial soils is very limited.

The surficial soils are predominantly coarse-grained covering approximately 90 to 95 percent of the area. They consist of gravelly, silty, and/or clayey sands and sandy gravels. The fine-grained soils consist of non-plastic to slightly plastic

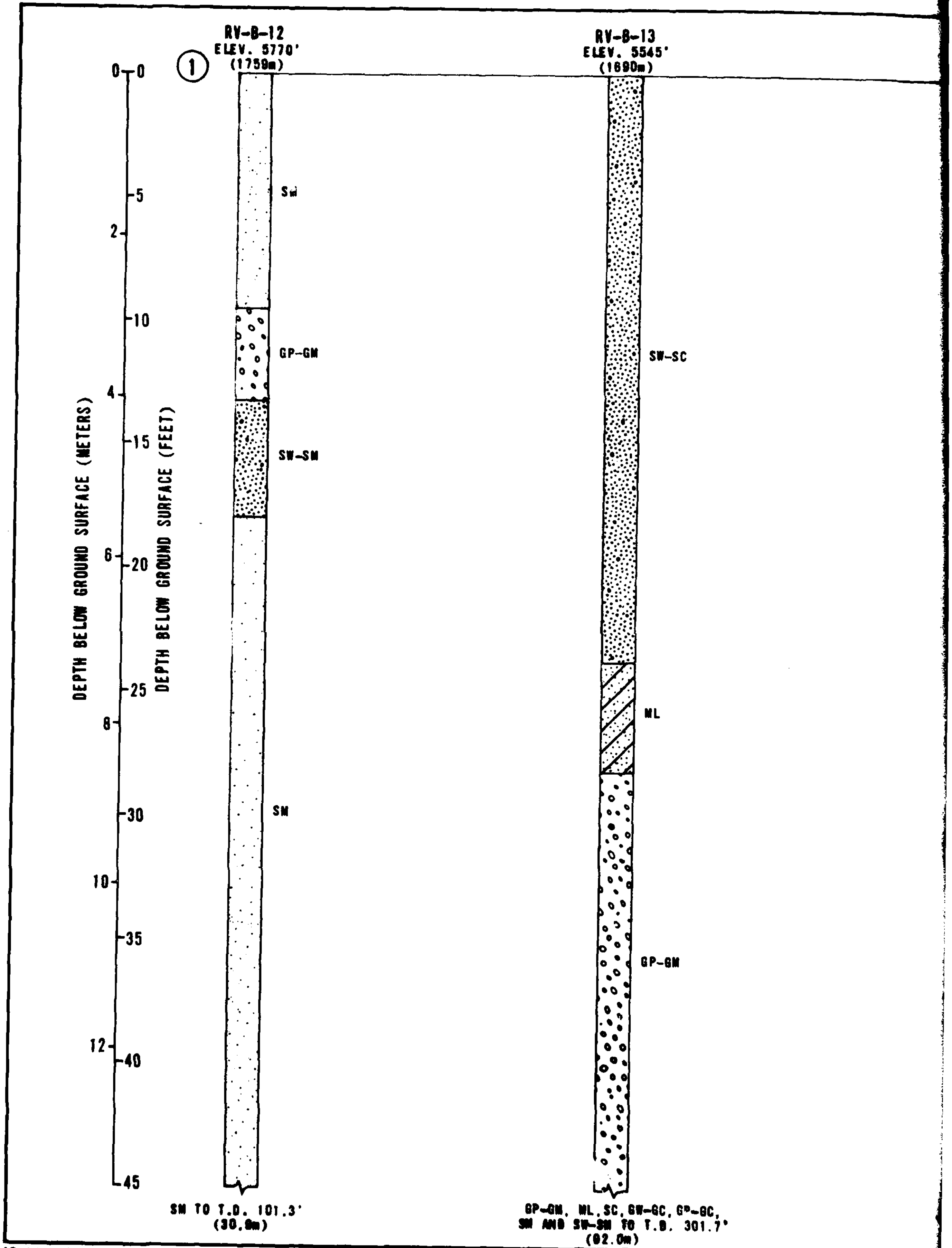
silts and clays. The surficial soils have variable calcium carbonate cementation.

3.4 SUBSURFACE SOILS

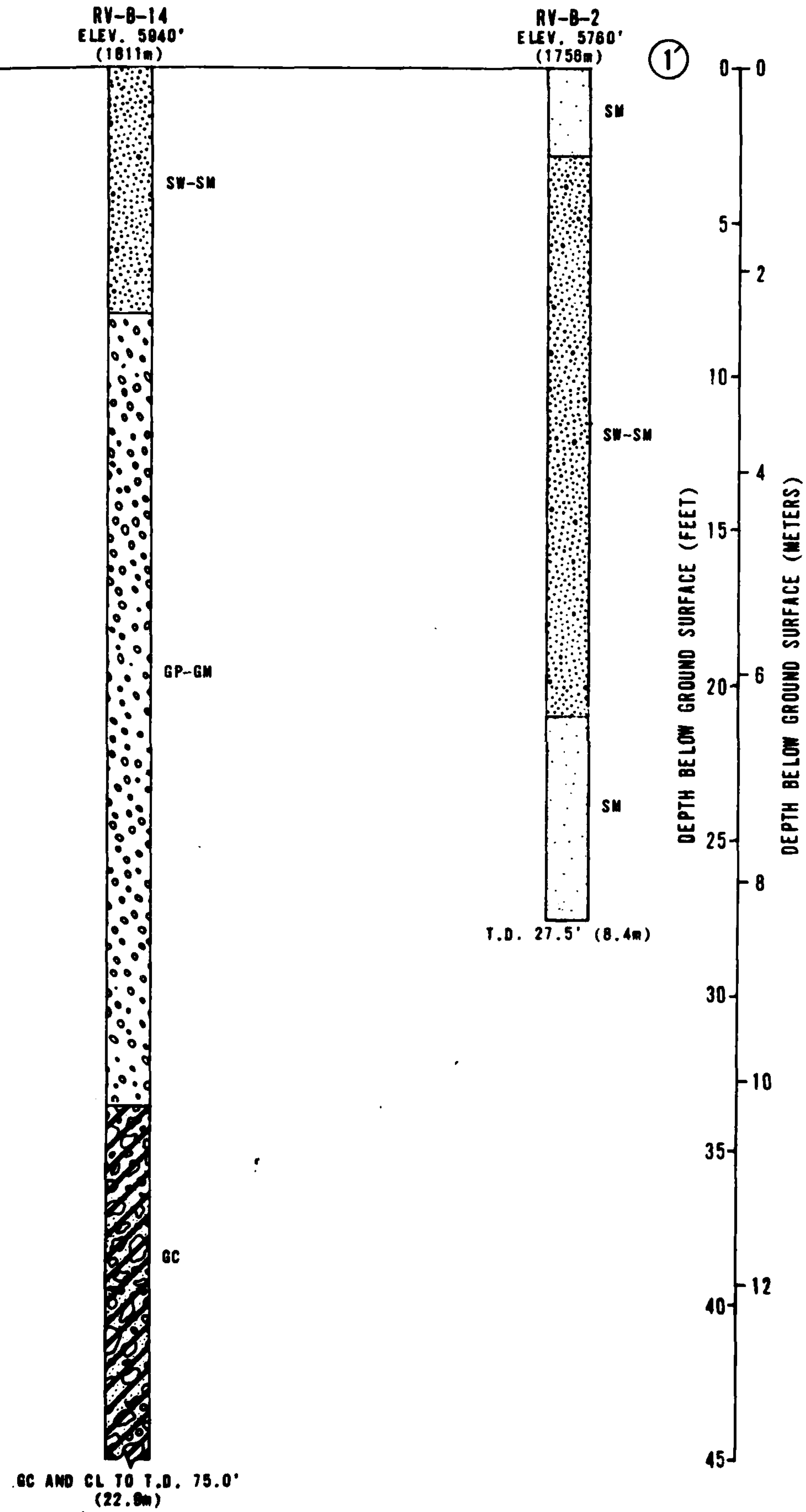
Subsurface soils are predominantly coarse-grained (granular) with only a limited extent of fine-grained soils present in the southern extremities of the valley near Mud Lake. The coarse grained soils include sandy gravels, gravelly sands, silty sands, and clayey sands. Subsurface fine-grained soils are associated with the active playa at the southern end of the valley where borings encountered alternating layers of sand and silt or clay. Some interfingering of alluvial deposits and playa deposits is apparent just north of the active playa where borings also encountered alternating layers of sand and silt or clay. Fine-grained soils are estimated to compose five to ten percent of the subsurface deposits. The composition of subsurface soil with depth, as determined from borings is illustrated in the soil profiles presented in Figure 3-2 and 3-3.

The characteristics of subsurface soils, determined from field and laboratory tests, are presented in Table 3-1 and the ranges of gradation of the subsurface soils are shown in Figure 3-4.

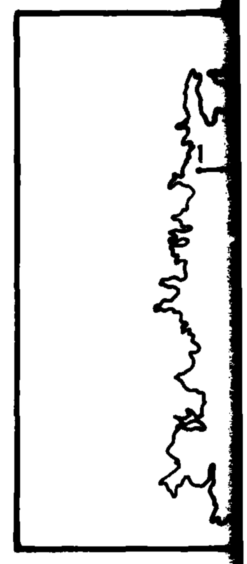
Coarse-grained subsurface soils are poorly to well graded, contain coarse to fine sands and gravels, and are medium dense to dense below 2 to 5 feet (0.6 to 1.5 m). Several of the coarse-grained soils contain appreciable fines and are classified as clayey sands or clayey gravels. Caliche development (cementation) ranges from none to moderate with thin lenses at shallow



RV-B-12
ELEV. 5770'
(1759m)
RV-B-13
ELEV. 5545'
(1690m)
1
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
SW
GP-GM
SW-SM
SM
SW-SC
ML
GP-GM
SM TO T.D. 101.3'
(30.9m)
GP-GM, ML, SC, GW-GC, GP-GC,
SM AND SW-SM TO T.D. 301.7'
(92.0m)



LO



EX

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil
Test location

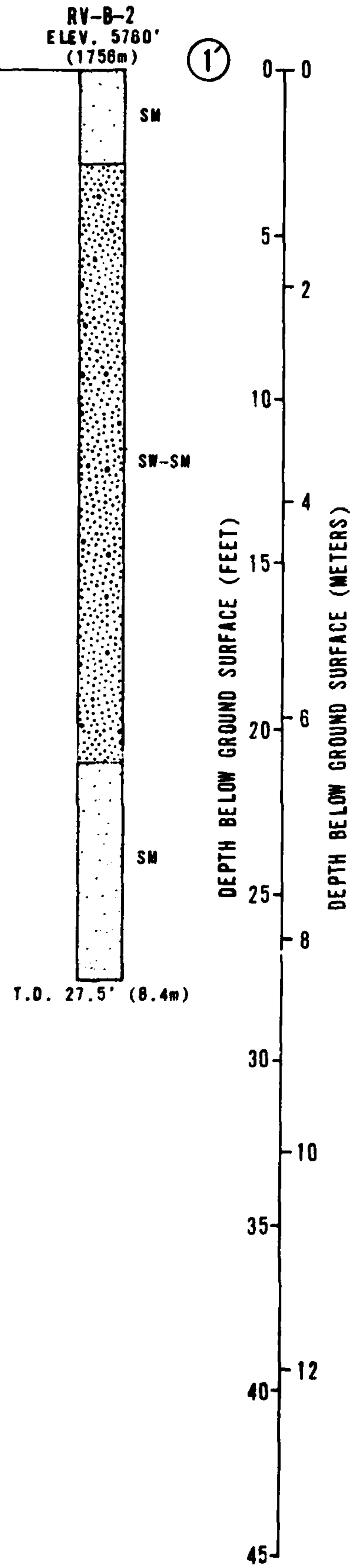
NOTES:

1. Ground surface elev
are approximate
2. T.D. = Total Depth
3. Soil types shown a
Unified Soil Classi
explained in the a

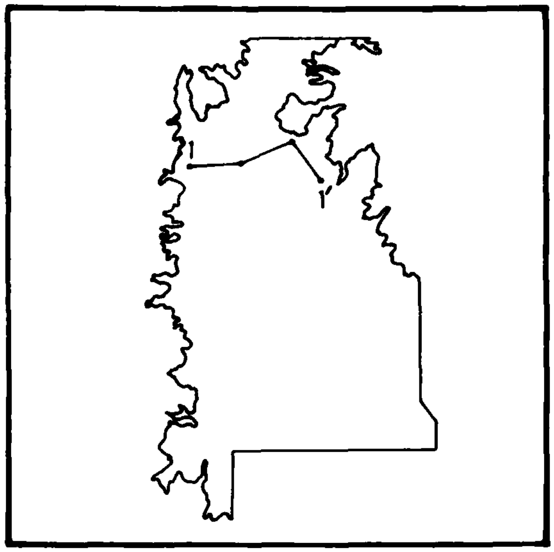
STATUTE MILES 0

KILOMETERS 0

DEPART



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

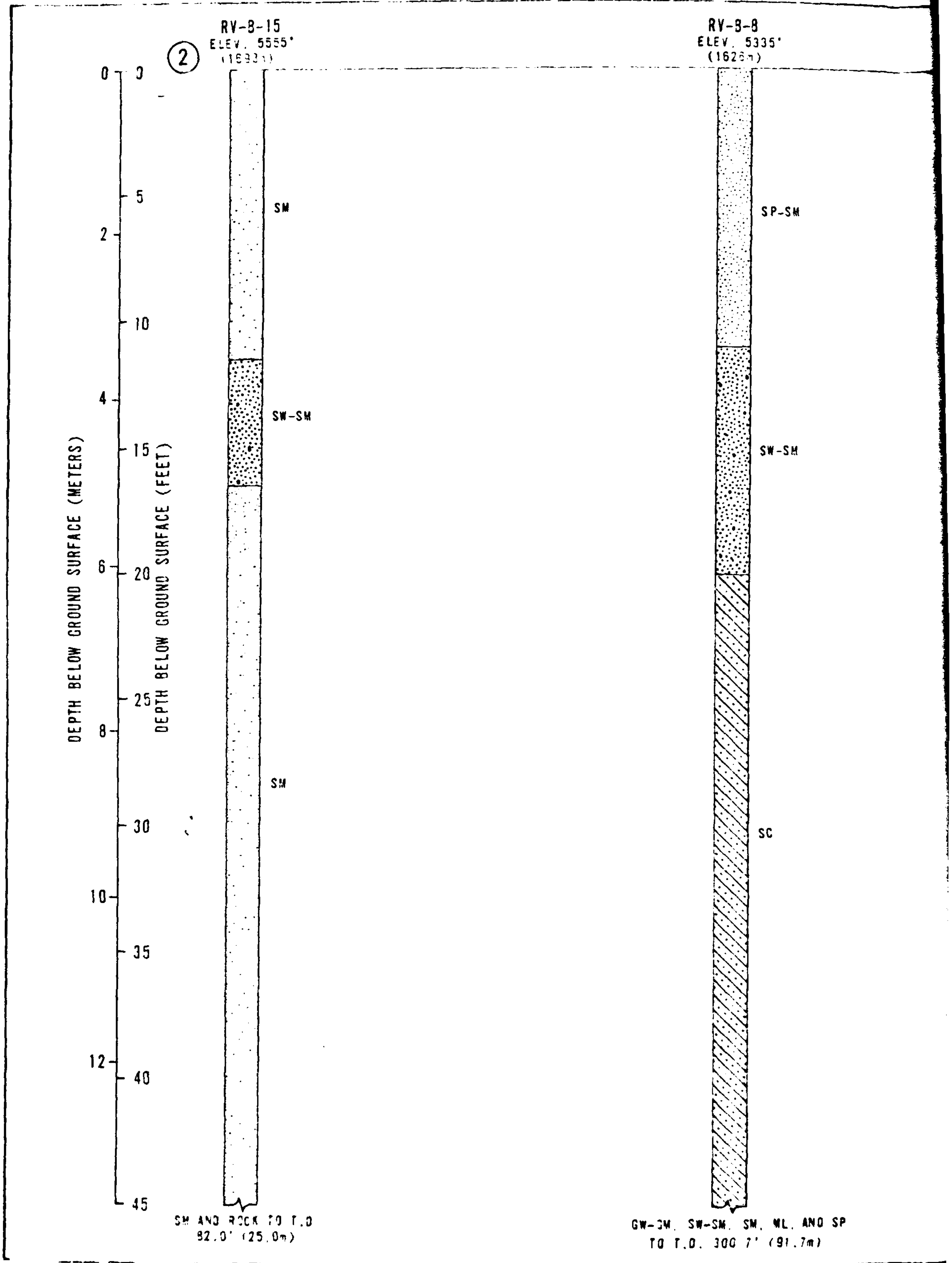
KILOMETERS 0 1 2 3

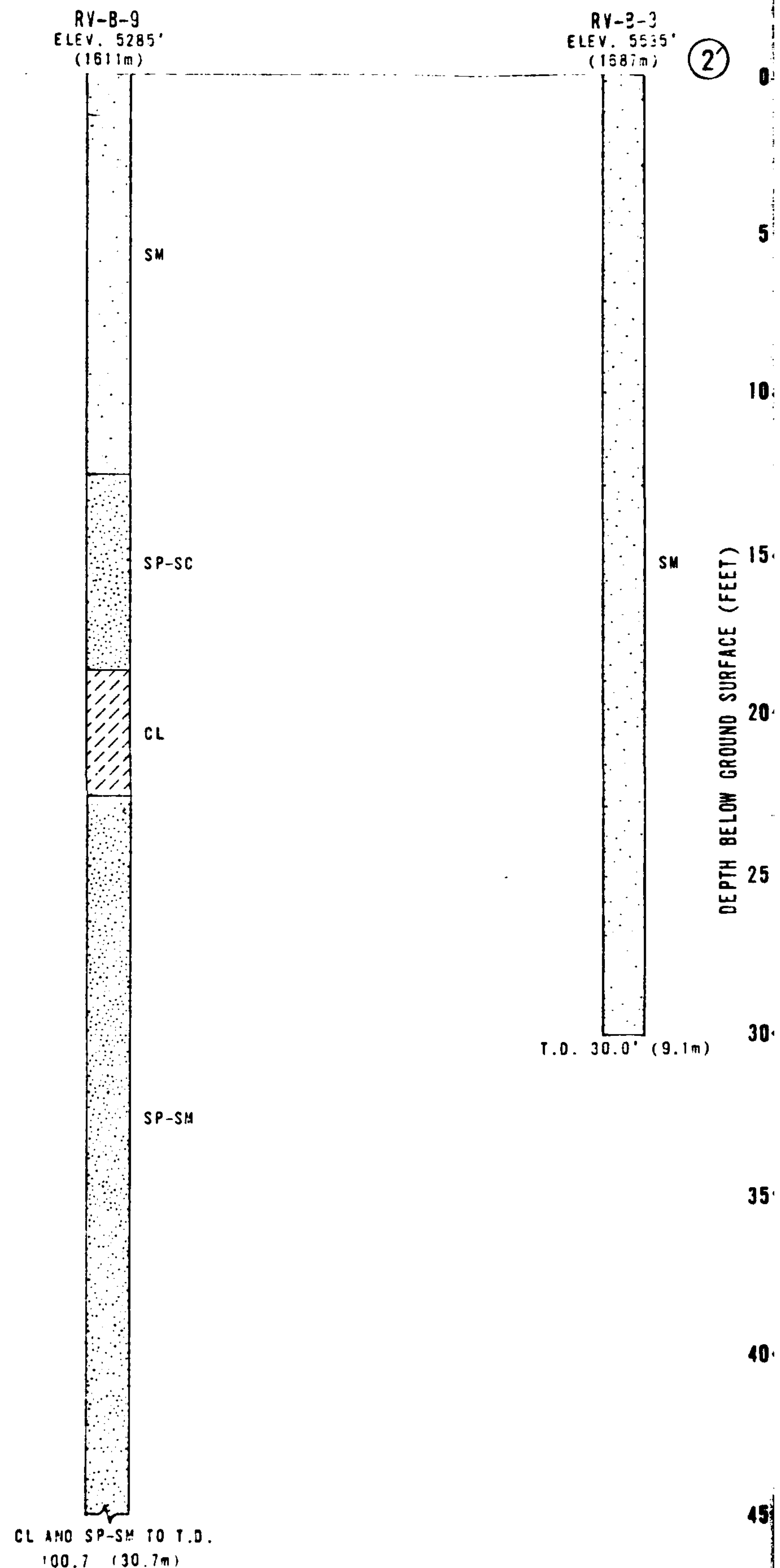
SOIL PROFILE 1-1' RALSTON VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-2

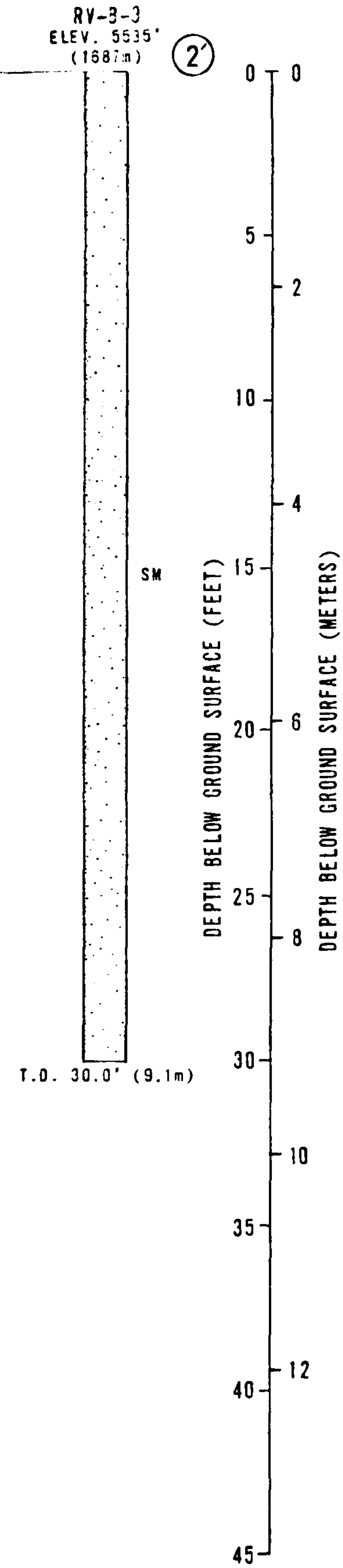
FUGRO NATIONAL, INC.

2

3


RV-B-15
ELEV. 5555'
(1693m)
RV-B-8
ELEV. 5335'
(1626m)
2
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
SM
SW-SM
SM
SP-SM
SW-SM
SC
SM AND ROCK TO T.D
82.0' (25.0m)
GW-GM, SW-SM, SM, ML, AND SP
TO T.D. 300.7' (91.7m)


RV-B-9
ELEV. 5285'
(1611m)
SM
SP-SC
CL
SP-SM
CL AND SP-SM TO T.D.
100.7 (30.7m)
RV-B-3
ELEV. 5535'
(1687m)
2
SM
T.D. 30.0' (9.1m)
DEPTH BELOW GROUND SURFACE (FEET)
0
5
10
15
20
25
30
35
40
45



LOCATION MAP

EXPLANATION

B- Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test Location

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

SOIL PROFILE 2-2' RALSTON VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-3

FUGRO NATIONAL, INC.

DEPTH RANGE		2' - 20' (0.6
SOIL DESCRIPTION	Coarse-grained soils	
	Sandy Gravels, Gravelly Sands, and Silty Sands	
USCS SYMBOLS	GW, GP, SP, SM	
ESTIMATED EXTENT IN SUBSURFACE %	90–95	
PHYSICAL PROPERTIES		
DRY DENSITY pcf (kg/m^3)	87.0–116.4 (1394–1865)	[14]
MOISTURE CONTENT %	3.8–17.8	[14]
DEGREE OF CEMENTATION	none to moderate	
COBBLES 3 – 12 inches (8 – 30 cm) %	0-10	
GRAVEL %	0–83	[46]
SAND %	16–86	[46]
SILT AND CLAY %	1–45	[47]
LIQUID LIMIT	25	[1]
PLASTICITY INDEX	NP–7	[4]
COMPRESSIONAL WAVE VELOCITY fps (mps)	940–4950 (286–1509)	[29]
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION S_u – ksf (kN/m^2)	NDA	
TRIAXIAL COMPRESSION c – ksf (kN/m^2), $\phi°$	c = 0 (0) = 48°–59°	[8]
DIRECT SHEAR c – ksf (kN/m^2), $\phi°$	c = 0 (0) = 32°–57°	[13]

NOTES:

- Characteristics of soils between 2 and 20 feet (0.6 and 6.0 meters) are based on results of tests on samples from 15 borings, and 8 trenches, and results of 15 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 13 borings and results of 15 seismic refraction surveys.

(0.6 - 6.0m)	20' - 160' (6.0 - 49.0m)	
Fine-grained soils	Coarse-grained soils	Fine-grained soils
NDA	Sandy Gravels, Gravelly Sands, Silty Sands, and Clayey Sands	Sandy Silts and Sandy Clays
	GW, GC, SP, SM, SC	ML, CL
	90-95	5-10
	80.9-122.5 (1296-1962) [67]	83.6-110.0 (1339-1762) [11]
	5.4-27.9 [67]	9.6-24.2 [11]
	none to moderate	none to moderate
	0-10	0
	0-74 [62]	0-15 [11]
	22-87 [62]	13-50 [11]
	3-48 [62]	50-87 [12]
	32-36 [5]	26-27 [2]
	NP-20 [6]	NP-5 [6]
	1670-5650 (509-1722) [21]	2250-3250 (686-991) [6]
	2.1 (101) [1]	2.8-14.4 (134-689) [3]
	c = 0 (0) c = 22°-49° [15]	NDA
	c = 0 (0) = 39°-56° [4]	c = 0 (0) ϕ = 35° [1]

- [ ] - Number of tests performed.
- NDA - No data available (insufficient data or tests not performed.)

CHARACTERISTICS OF SUBSURFACE SOILS
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-1

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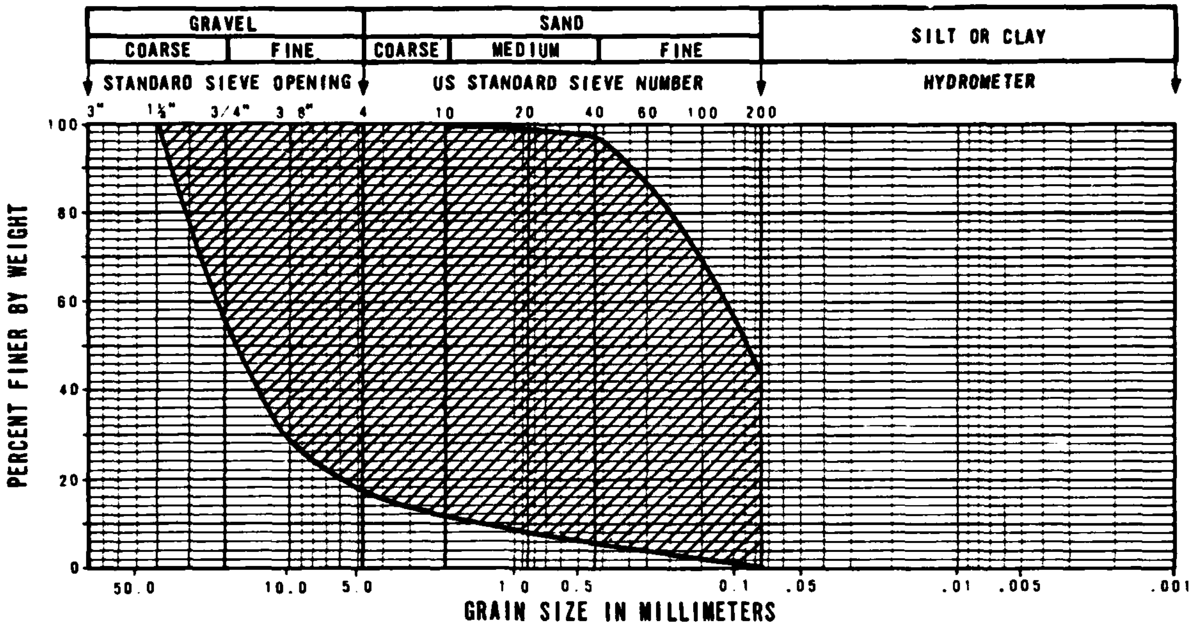
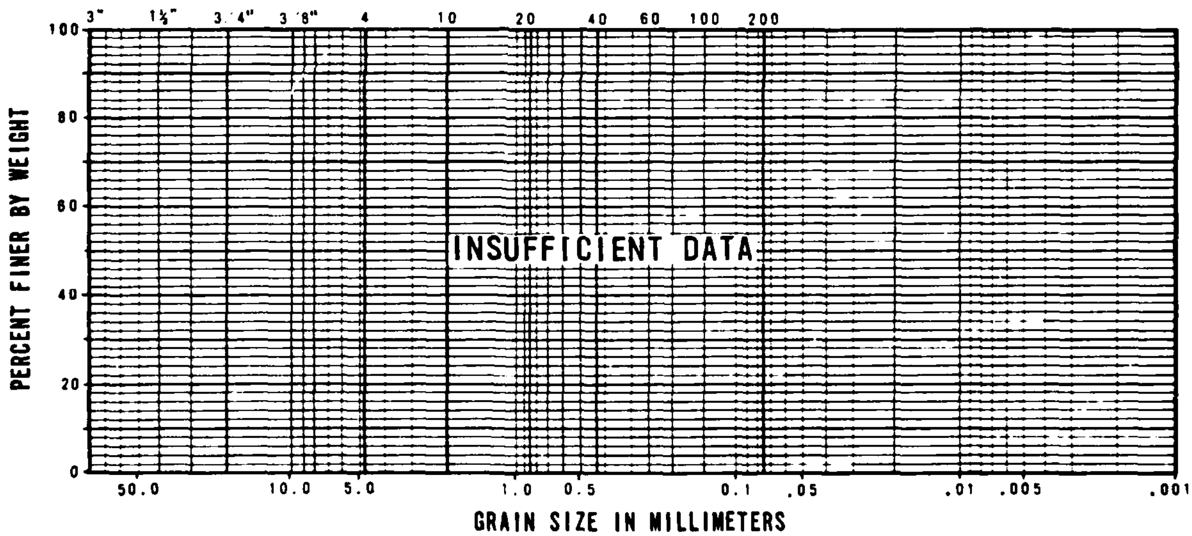
AFV-



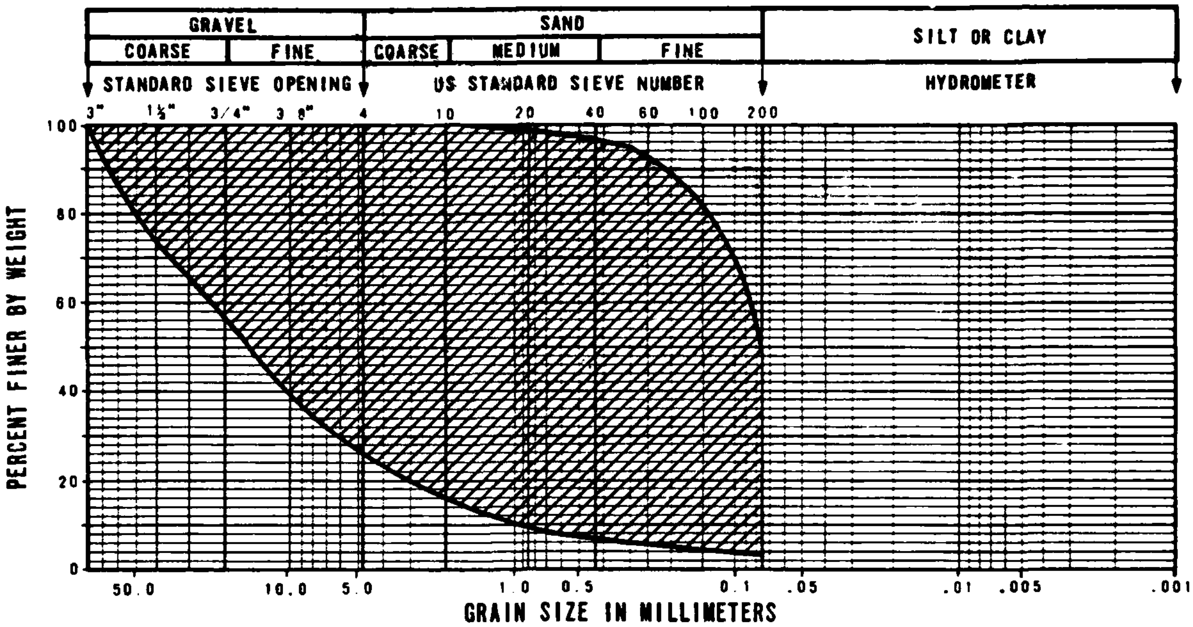
SOIL DESCRIPTION: Coarse-Grained Soils
from 2 to 20 feet (0.6-6.0m)



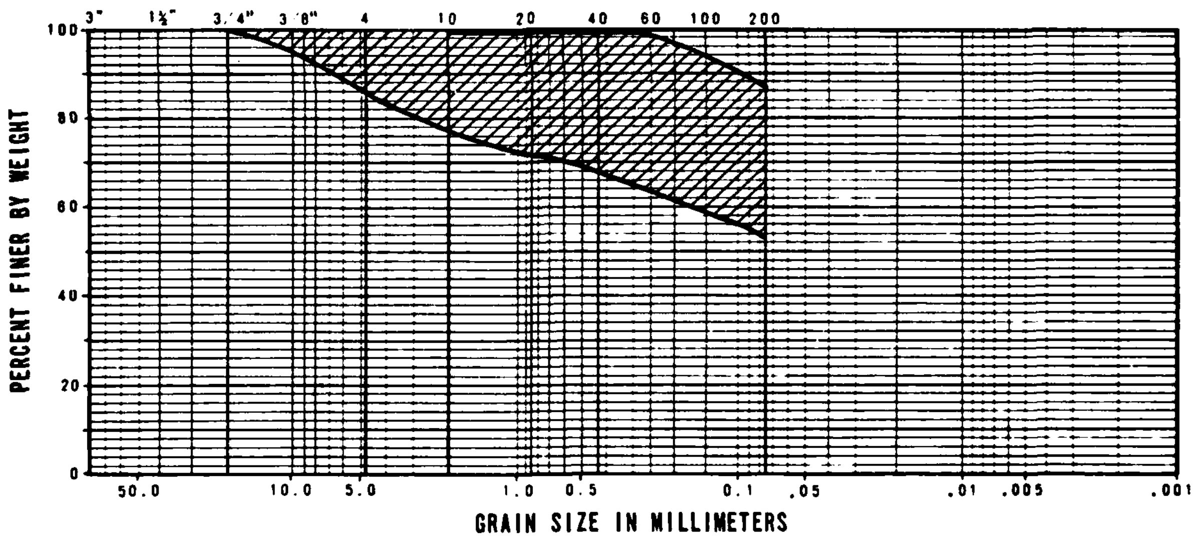
SOIL DESCRIPTION: Fine-Grained Soils
from 2 to 20 feet (0.6-6.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS RALSTON VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-4 1 OF 2

FUGRO NATIONAL, INC.



SOIL DESCRIPTION: Coarse-Grained Soils
from 20 to 160 feet (6.0–49.0m)



SOIL DESCRIPTION: Fine-Grained Soils
from 20 to 160 feet (6.0–49.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-4
2 OF 2

FUGRO NATIONAL, INC.

depths. These soils exhibit low compressibilities and moderate to high shear strength. Fine-grained soils (sandy silts and sandy clays) range in consistency from soft to hard and exhibit low to moderate compressibilities and low to high shear strengths. Soil plasticity ranges from none to slight. Calcium carbonate cementation varies from weak to moderate. Results of shallow seismic surveys are summarized in Table 3-2 and Table 3-3 contains the velocity profiles from the deep seismic surveys.

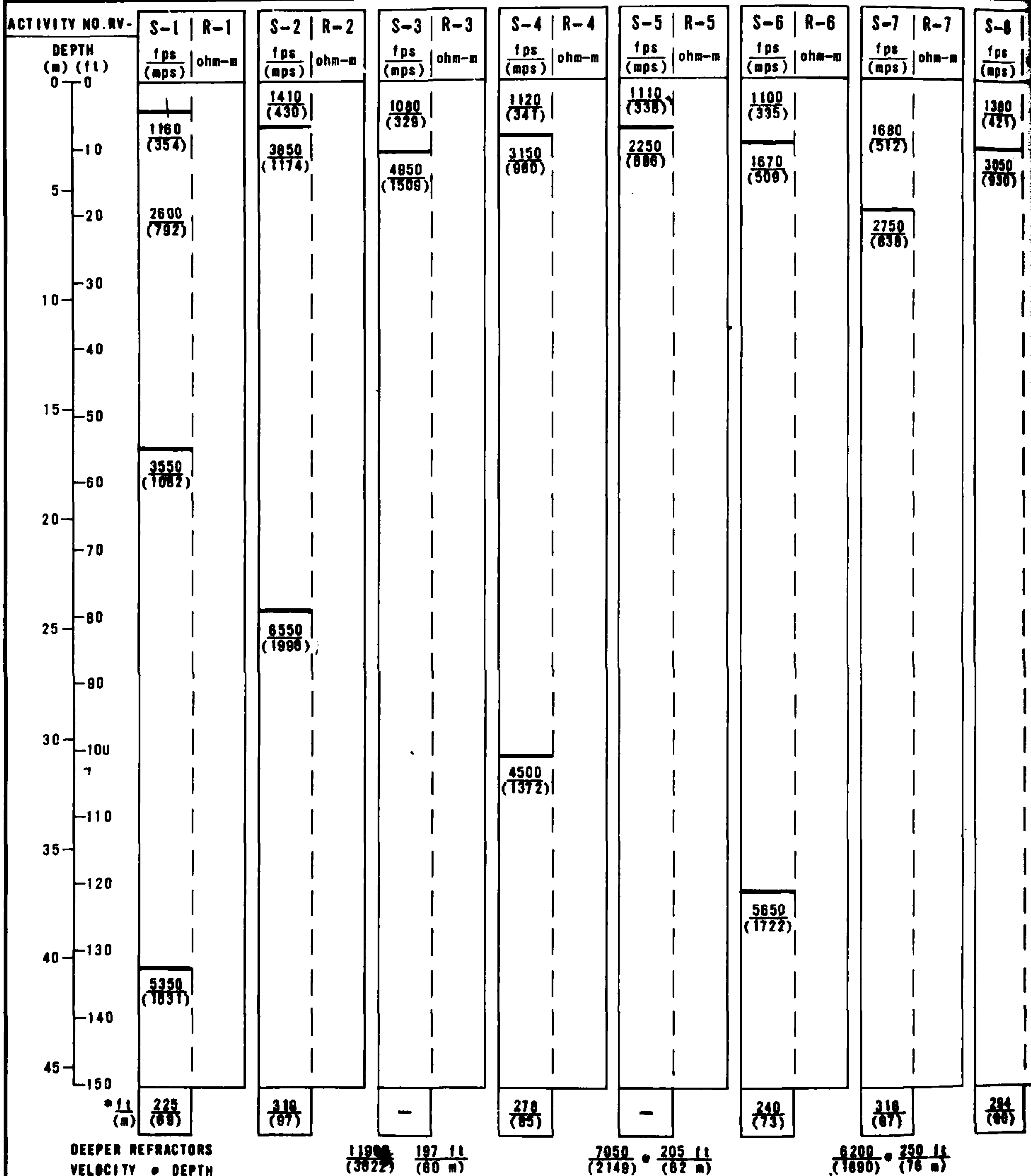
The soils in the construction zone (120 feet; 37 m) have a wide range of seismic compressional wave velocities (940 to 5650 fps; 287 to 1724 mps), depending on their composition, consistency, cementation, and moisture content.

Seismic shear wave velocities (Table 3-4) were measured at three locations. In the upper 20 feet (6 m) they ranged from 540 fps (165 mps) to 1600 fps (488 mps). From 20 feet (6 m) to 140 feet (43 m) depth they ranged from 1600 fps (488 mps) to 3000 fps (914 mps).

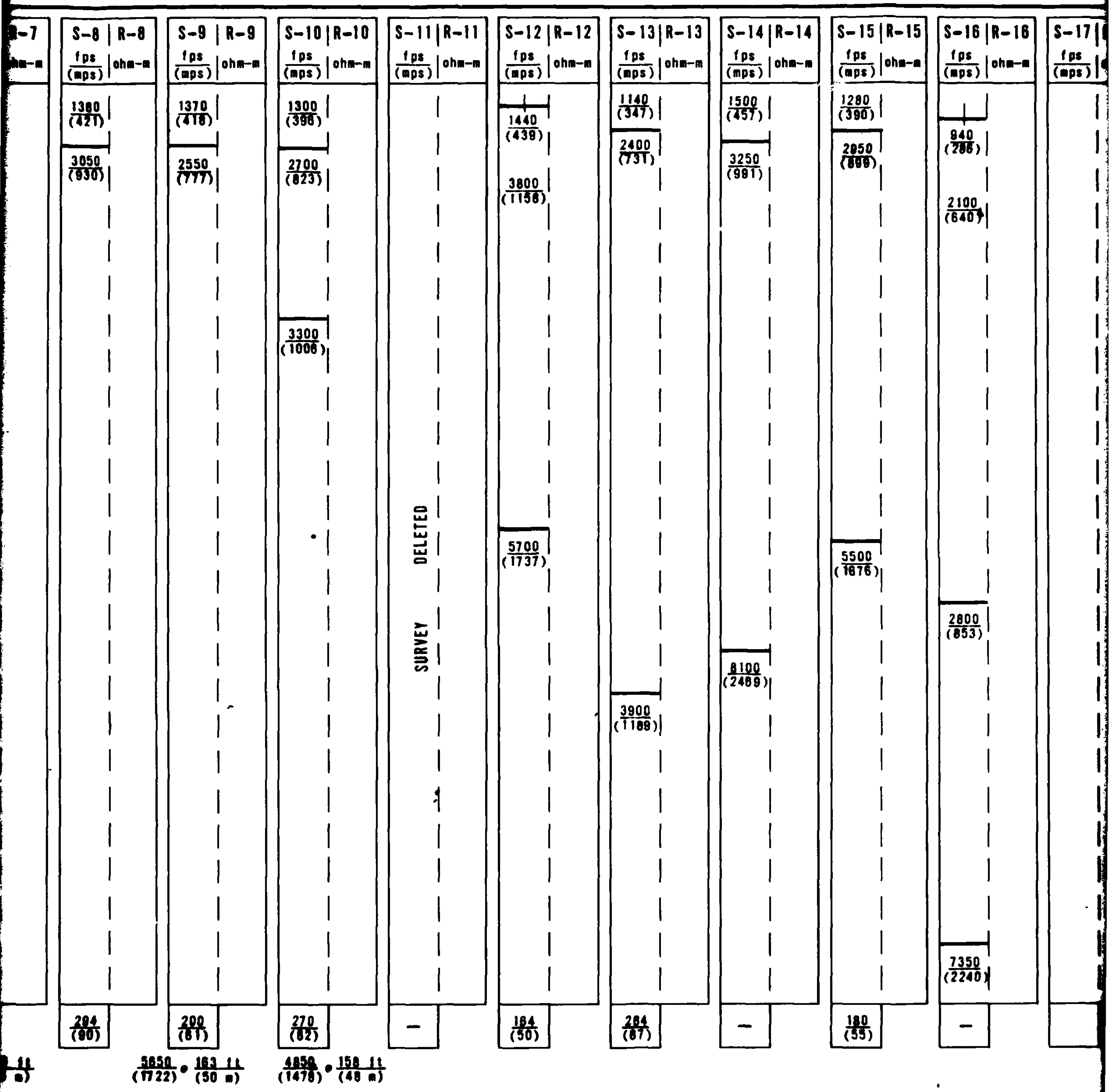
Results of chemical tests indicate that potential for sulfate attack of soils on concrete will range from "negligible" to "considerable."

3.5 DEPTH TO ROCK

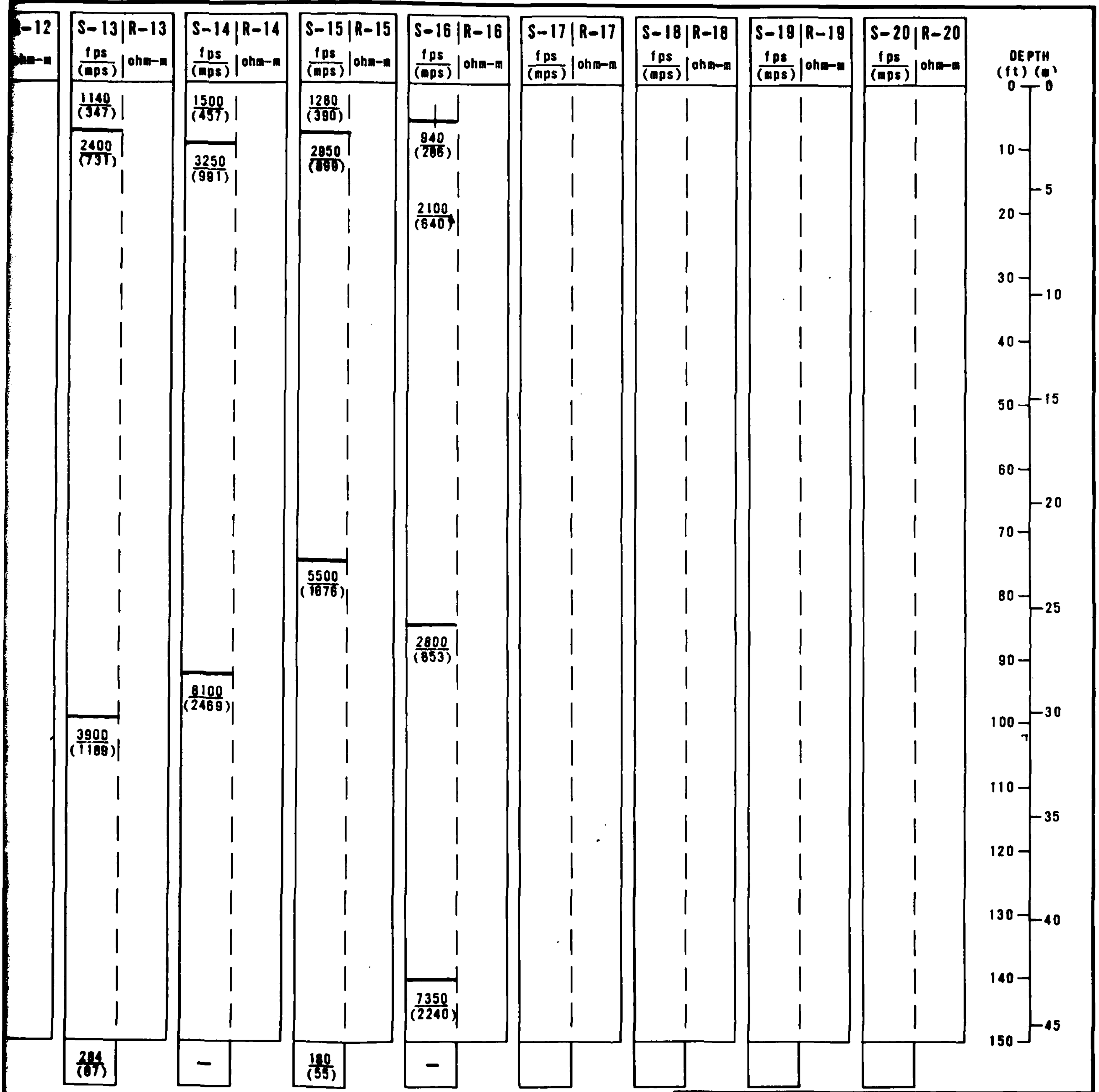
Drawing 3-3 shows the approximate configuration of 50- and 150-foot (15- and 46m) depth to rock contours in Ralston Valley. This interpretation is based on limited point data from borings,



* Approximate depth above which there is no indication of material with a velocity as great as 7000 fps (2134mps). See Appendix A for an explanation of how this exlusion depth is calculated when the observed velocities are all less then 7000 fps (2134 mps).



R-7
ohm-m
S-8 | R-8
fps (mps) | ohm-m
1380 (421)
3050 (930)
294 (90)
S-9 | R-9
fps (mps) | ohm-m
1370 (418)
2550 (777)
200 (61)
S-10 | R-10
fps (mps) | ohm-m
1300 (396)
2700 (823)
3300 (1006)
270 (82)
S-11 | R-11
fps (mps) | ohm-m
SURVEY DELETED
—
S-12 | R-12
fps (mps) | ohm-m
1440 (439)
3800 (1158)
5700 (1737)
164 (50)
S-13 | R-13
fps (mps) | ohm-m
1140 (347)
2400 (731)
3900 (1189)
284 (87)
S-14 | R-14
fps (mps) | ohm-m
1500 (457)
3250 (991)
8100 (2469)
—
S-15 | R-15
fps (mps) | ohm-m
1280 (390)
2950 (899)
5500 (1676)
180 (55)
S-16 | R-16
fps (mps) | ohm-m
940 (286)
2100 (640)
2800 (853)
7350 (2240)
—
S-17
fps (mps)
5650 (1722) @ 163 ft (50 m)
4850 (1478) @ 158 ft (48 m)



SHALLOW SEISMIC REFRACTION VELOCITY PROFILES
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

TABLE 3-2

FUGRO NATIONAL, INC.

AFV-18

2 v 3

VELOCITY LAYER	COMPRESSIONAL WAVE VELOCITY FPS (MPS)	AVERAGE THICKNESS FT (M)	COMMENTS
1	2600-3100 (792-945)	100 (30)	-
2	4000-5200 (1219-1585)	300 (91)	-
3	7700-8500 (2347-2591)	400 (122)	-
4	10,500-11,300 (3200-3444)	1200 (366)	-
5	13,600 (4145)	2800 (853)	-
6	18,800 (5730)	UNKNOWN	BASEMENT

LINE RV-DS-1

VELOCITY LAYER	COMPRESSIONAL WAVE VELOCITY FPS (MPS)	AVERAGE THICKNESS FT (M)	COMMENTS
1	2500-3200 (762-975)	50 (15)	-
2	4500-5100 (1372-1554)	300 (91)	PINCHES OUT
3	7300 (2225)	200 (61)	PINCHES OUT
4	10,700 (3261)	500 (152)	-
5	13,600 (4145)	2300 (701)	-
6	18,800 (5730)	UNKNOWN	BASEMENT

LINE RV-DS-2

DEEP SEISMIC REFRACTION VELOCITY PROFILES
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-3

FUGRO NATIONAL, INC.

DOWNHOLE SURVEY NO.	VELOCITY DISTRIBUTION FPS (MPS)			WAVE TYPE
RV-DV-5	1730 (527)	2250 (686)		P WAVE
	1100 (335)	1420 (433)		S WAVE
RV-DV-8	1500 (457)	2020 (616)	4000 (1219)	P WAVE
	940 (287)	1280 (390)	2460 (750)	S WAVE
RV-DV-12	1800 (549)	2300 (701)	4400 (1341)	P WAVE
	1000 (305)	1600 (488)	3000 (914)	S WAVE

METERS 0 5 10 15 20 25 30 35 40 45

FEET 0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

DEPTH INTERVAL

DOWNHOLE SEISMIC VELOCITY PROFILES
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-4

FUGRO NATIONAL, INC.

seismic refraction surveys, site-specific published data, and depths inferred from geologic and geomorphic relationships. Approximately 21 percent of the basin-fill material in the valley is interpreted to be underlain by rock at depths of less than 50 feet. An additional nine percent of the valley is interpreted to contain shallow rock between depths of 50 and 150 feet.

The depth to rock interpretation represents subsurface projections of surface rock, tempered by data from two of the borings and seismic lines. For this reason, contours generally parallel exposed rock in the valley.

Several areas, along the periphery of the valley are interpreted to be underlain by shallow rock (Drawings 3-2 and 3-3). These areas are generally small and probably represent remnants of volcanic flows. Geographically, they are all adjacent to volcanic rock outcrops.

3.6 DEPTH TO WATER

Drawing 3-4 shows the locations of all data points used to define ground-water conditions in Ralston Valley. The sources of these data are: Eakin, 1962; USGS, 1980; Robinson and others, 1967; and Nevada State Engineers Office, 1974. Nine wells drilled in basin fill materials indicate that ground water exists at a depth generally greater than 200 feet throughout the center of the valley. The only observed shallow water is in the northern end of the valley just west of Thunder Mountain where a well field has been developed for use by the town of Tonopah.

The presence of shallow water near Thunder Mountain has been explained as being the result of bedrock topography constricting or impounding the flow of ground water through the valley fill (Eakin, 1962). Water level profiles (Eakin, 1962), indicate that a fairly major change in ground-water level occurs north of well W6 (Drawing 3-4). Ground water at well W6 is 480 feet (146 m) deep, while at Thunder Mountain it is less than 50 feet (15 m). This difference in depth is interpreted to indicate a ground-water barrier between Thunder Mountain and well W6. Ekren and others (1976) propose that the Warm Springs topographic/structural lineament crosses the San Antonio Mountains about 4 miles (7 km) north of Tonopah and passes south of Thunder Mountain. This lineament, if present, may be the postulated subsurface ground-water barrier.

3.7 TERRAIN

Terrain conditions in Ralston Valley are depicted in Drawing 3-5. Terrain categories I through V correspond to alluvial fan or mixed alluvial fan and lacustrine deposits with varying amounts of stream incision. There were no areas interpreted as category VI terrain (highly variable). Where incision depths are extreme and where topographic slope exceeds ten percent, the terrain is considered unsuitable and has been excluded (category VII). Small areas with extreme incision occur on the western side of the valley near Mud Lake in the south, and near Thunder Mountain in the north. Other small areas with topographic

slopes exceeding ten percent occur along the mountain flanks and in many small canyon reentrants around the valley.

Ralston Valley is a topographically closed basin with a centrally located major drainage system that flows south towards Mud Lake. This drainage becomes poorly defined north of Mud Lake and carries surface run-off to the lake only during very wet seasons. Relief within the valley is on the order of 2000 feet (610 m). The lowest point in the valley is at Mud Lake (5200 ft., 1585 m); the highest (7185 ft.; 2190 m) is Mt. Butler, near Tonopah.

Intermediate alluvial fans near mountain fronts (terrain categories II through V) generally have stream incisions from 2 to 12 feet deep (0.6 to 3.7 m) with variable spacing. Surface slopes generally are less that four percent and average two to three percent in these areas.

Young alluvial fans (generally terrain category I) have incisions ranging from 0.3 to 1.0 foot (0.1 to 0.3 m), with an average of approximately 0.7 feet (0.2 m). Surface slopes vary from one to five percent, with the average near two to three percent.

Playa and alluvial/playa deposits have relief from 0 to 1 foot (0 to 0.3 m). Surface slopes average approximately one percent.

BIBLIOGRAPHY

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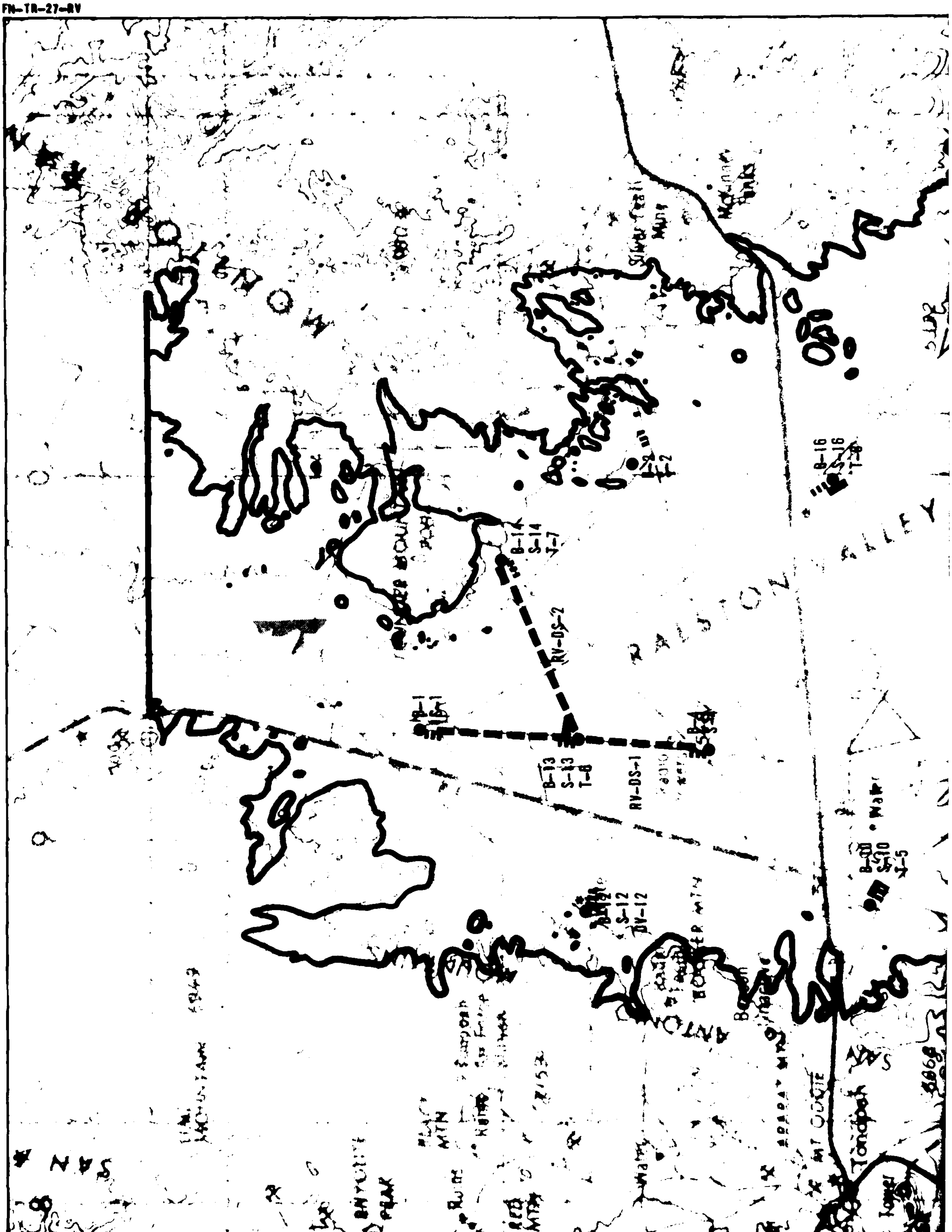
1

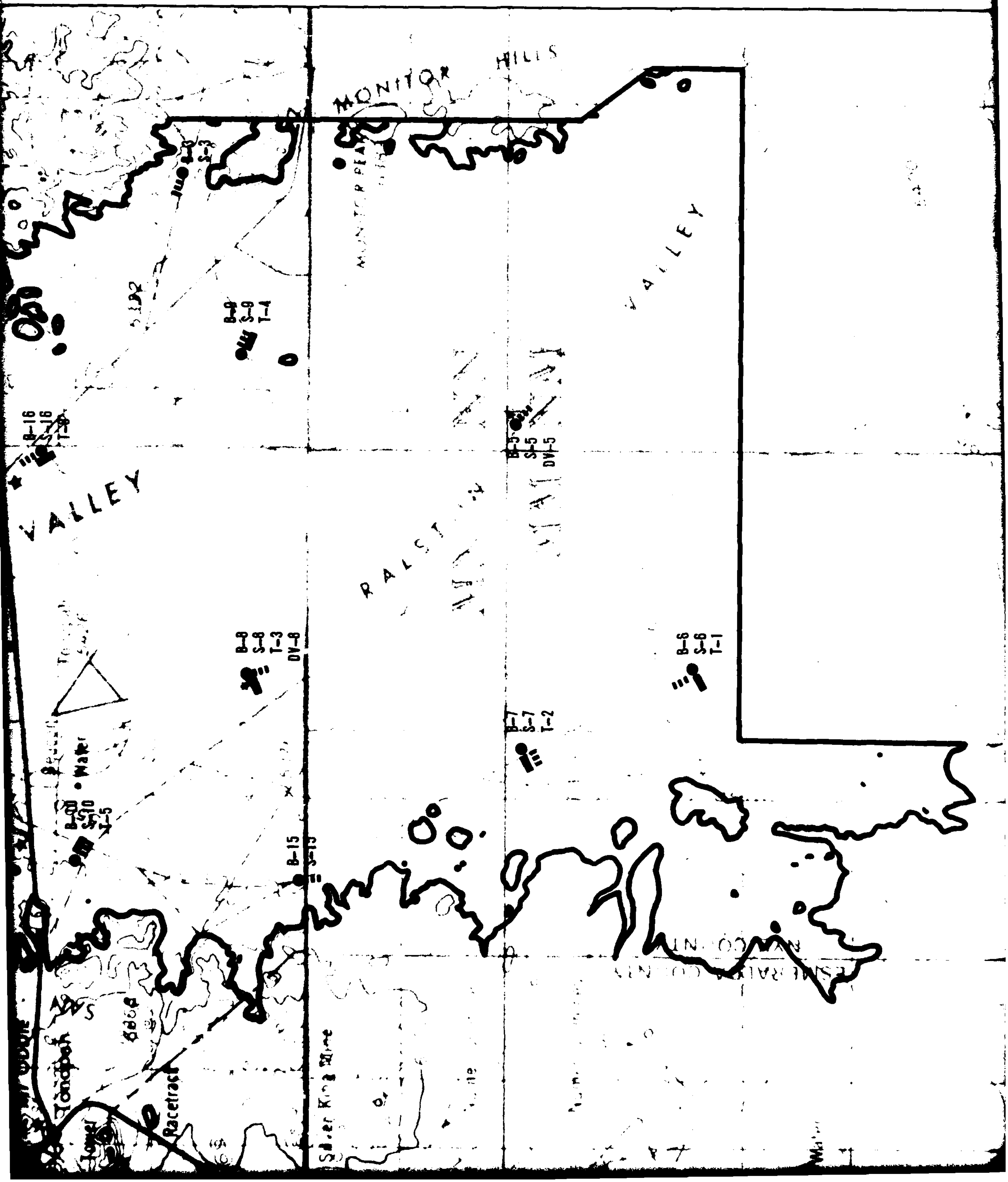
FN-TR-27-RV



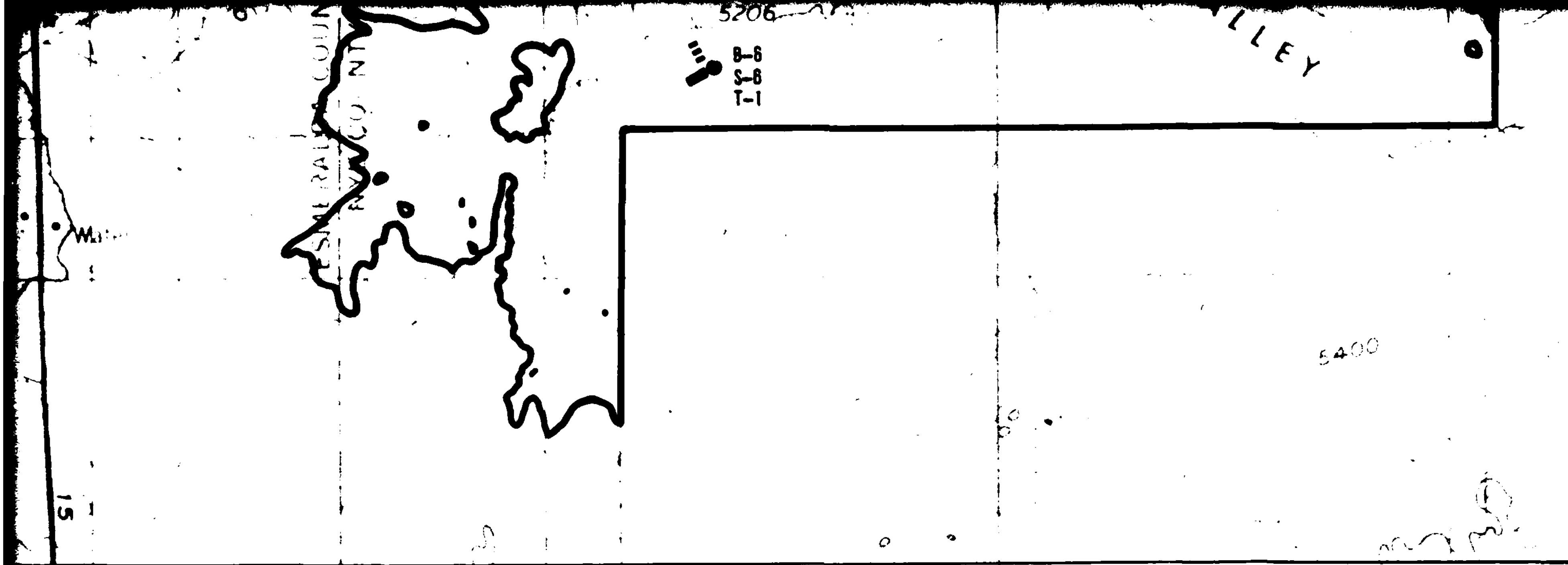
RALSTON VALLEY
RV-DS-2
RV-DS-1
B-14
S-14
T-7
B-13
S-13
T-8
B-12
S-12
Tonopah

1

2



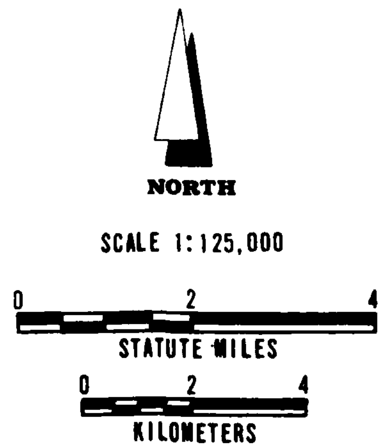
MONITOR HILLS
VALLEY
VALLEY
B-3
S-3
B-9
S-9
T-4
B-16
S-16
B-5
S-5
DV-5
B-8
S-8
T-3
DV-8
B-6
S-6
T-1
B-7
S-7
T-2
B-10
S-10
T-5
Water
B-15
S-15
Tonopah
Racetrack
Silver King Mine

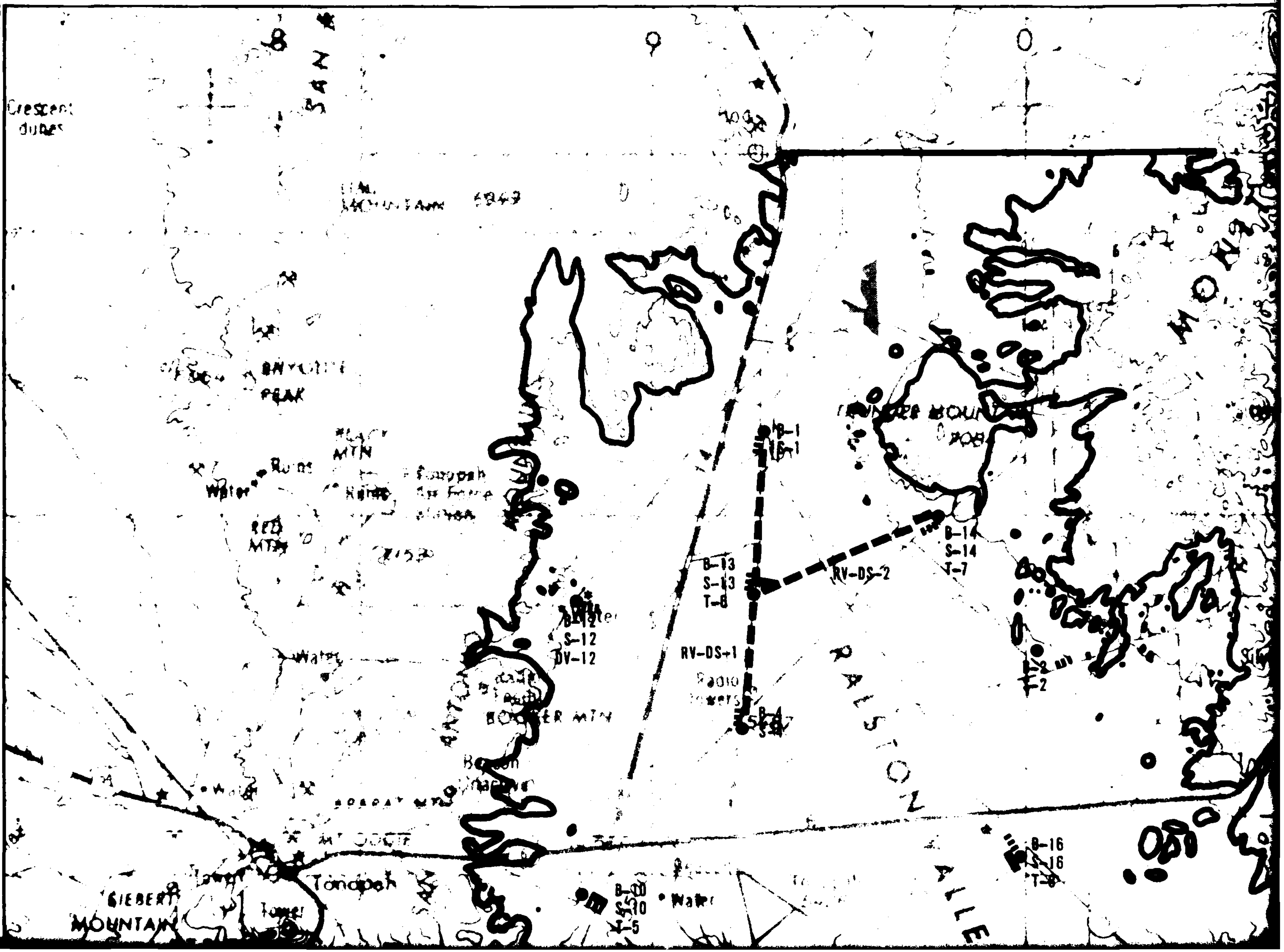


EXPLANATION

- ● B-1 BORING
- ▬ T-1 TRENCH
- ▪▪▪ S-1 SEISMIC REFRACTION LINE
- * DV-1 DOWNHOLE VELOCITY SURVEY
- ▬ ▬ ▬ RV-DS-1 DEEP SEISMIC REFRACTION LINE

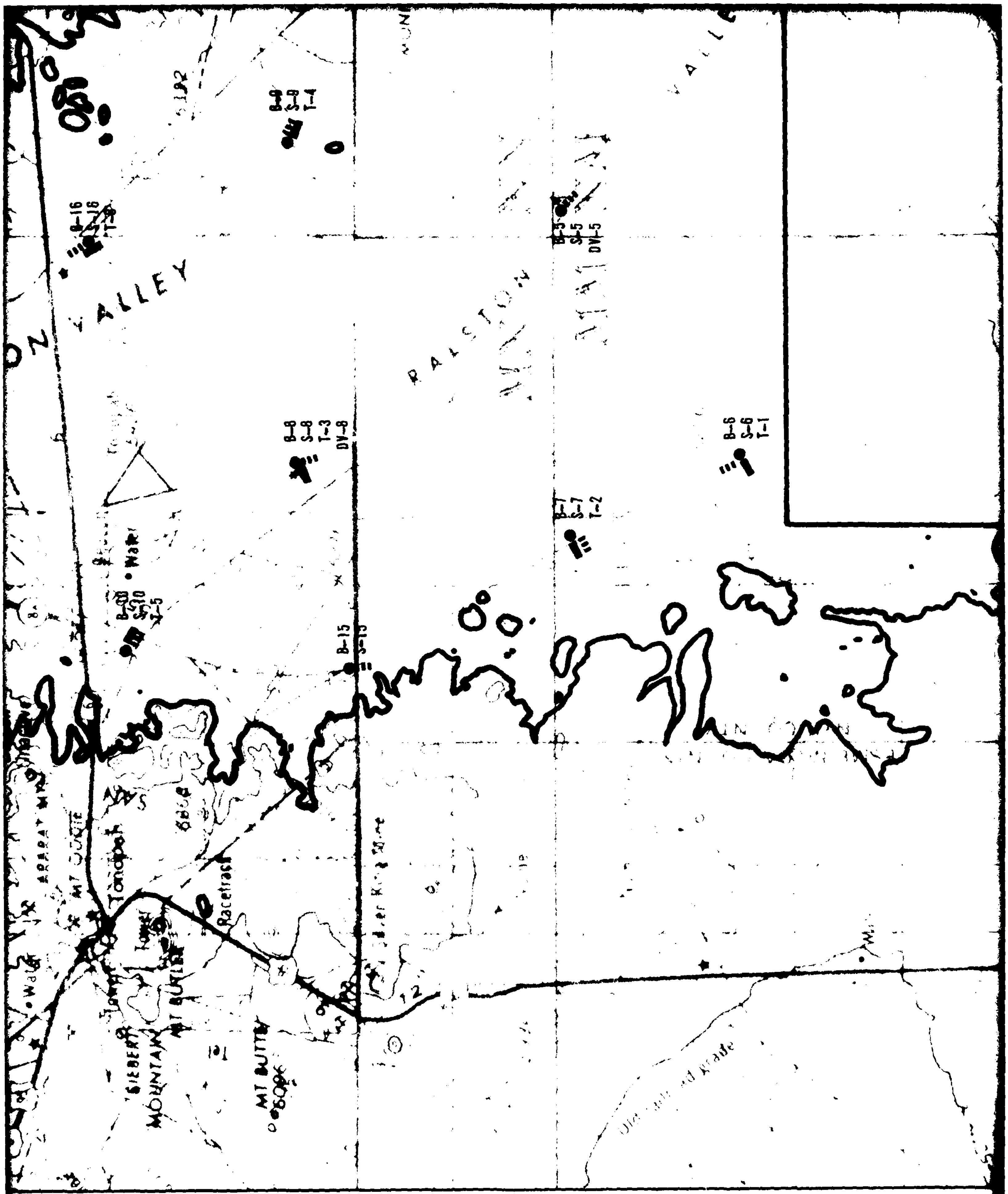
NOTE: Where multiple activities were performed at the same location, the correct location is designated by the boring.




Crescent dunes
SAN
6849
BAYOTTE PEAK
MTN
Tonopah
Water
Ruins
RED MTN
B-1
S-1
B-13
S-13
T-8
RV-DS-2
RV-DS-1
Radio towers
B-14
S-14
T-7
B-12
S-12
DV-12
MTN
Tonopah
SIEBERT MOUNTAIN
Tower
B-10
S-10
T-5
Water
B-16
S-16
T-8
RALSTON VALLEY
MON

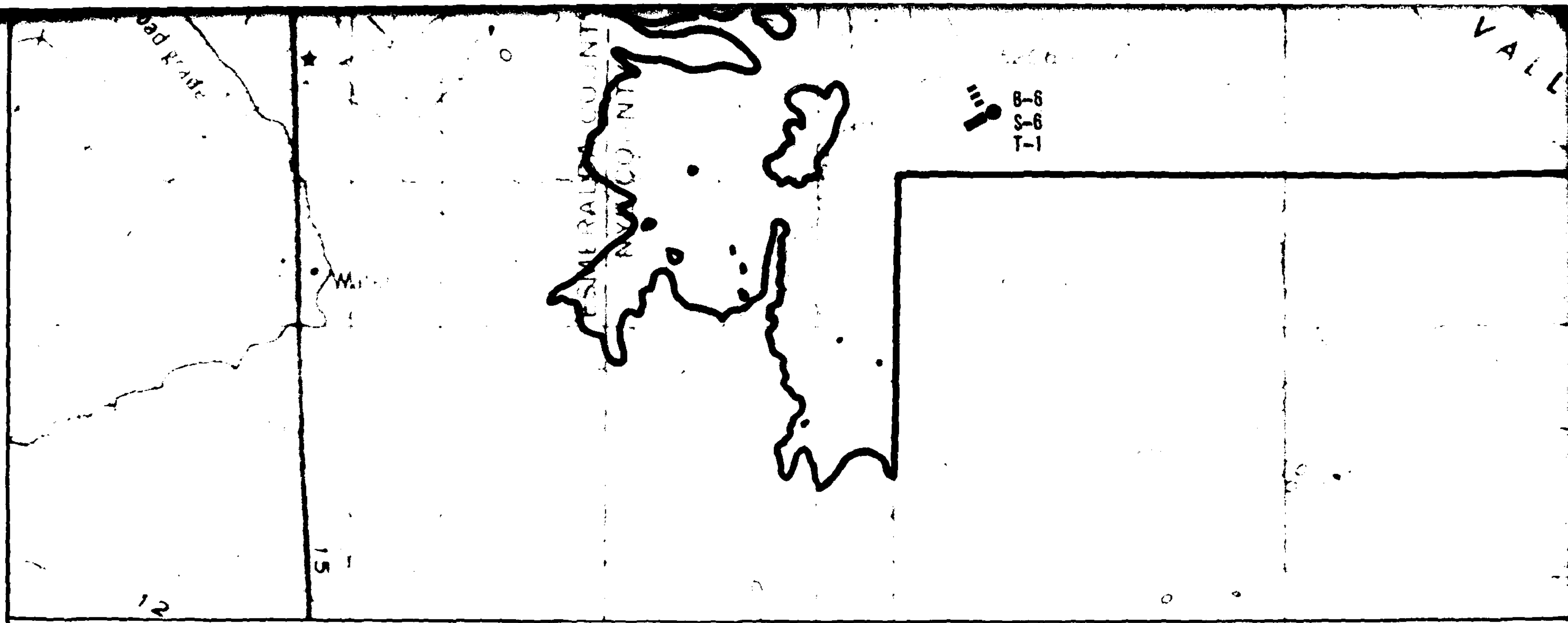
3

15 JUN 68



RALSTON
VALLEY
B-8
S-8
T-3
DV-8
B-6
S-6
T-1
B-7
S-7
T-2
B-5
S-5
DV-5
B-15
S-15
Tonopah
Racetrack
SIEBERT
MOUNTAIN

1 4.



EXPLANATION

- ● B-1 BORING
- ▬ T-1 TRENCH
- ▪▪▪ S-1 SEISMIC REFRACTION LINE
- * DV-1 DOWNHOLE VELOCITY SURVEY
- ▬ ▬ ▬ RV-DS-1 DEEP SEISMIC REFRACTION LINE

NOTE: Where multiple activities were performed at the same location, the correct location is designated by the boring.

SCALE 1

STATUTE

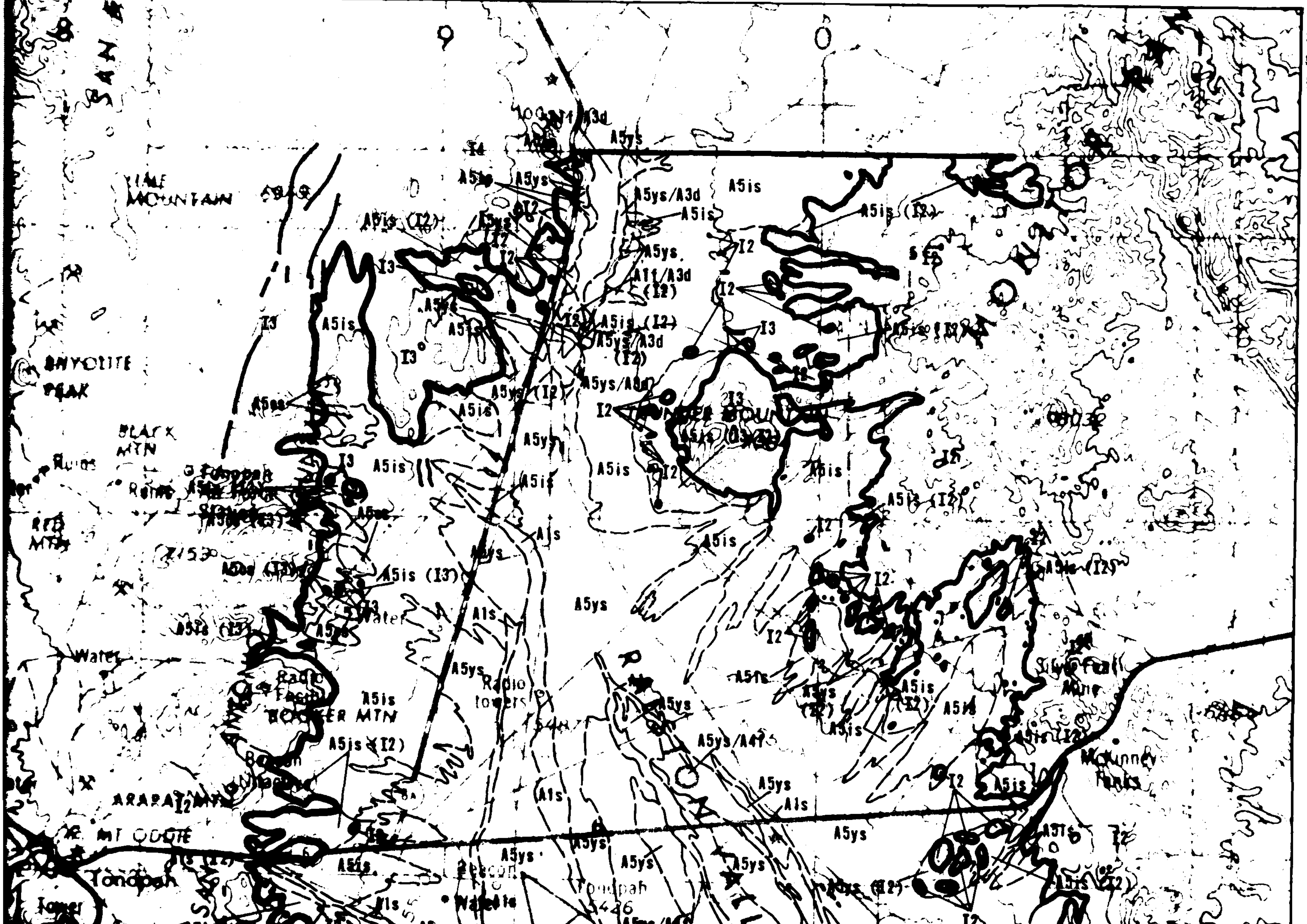
KILO

ACTIVITY LOCATIONS
RALSTON VALLEY, NEVADA

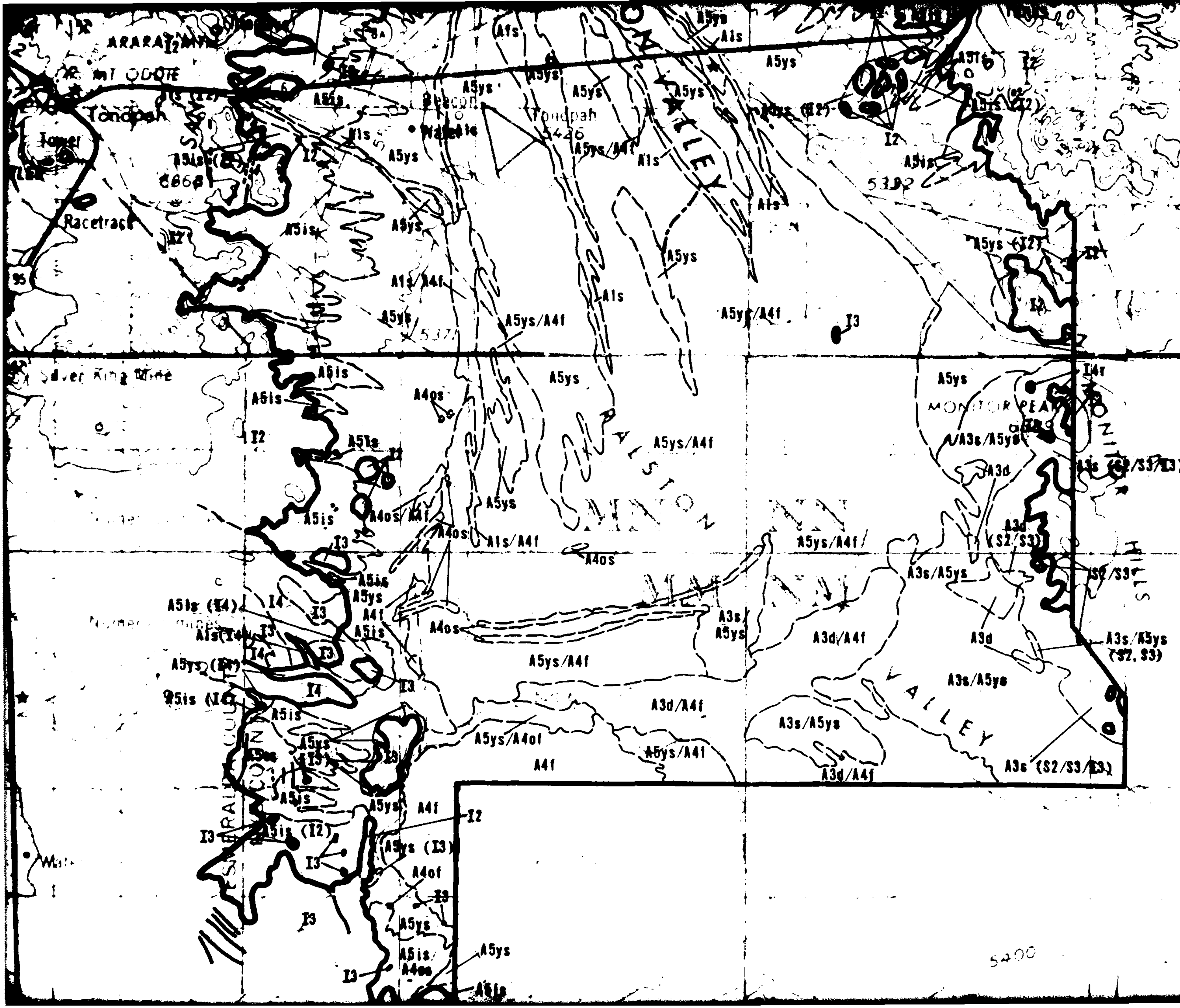
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - [redacted]

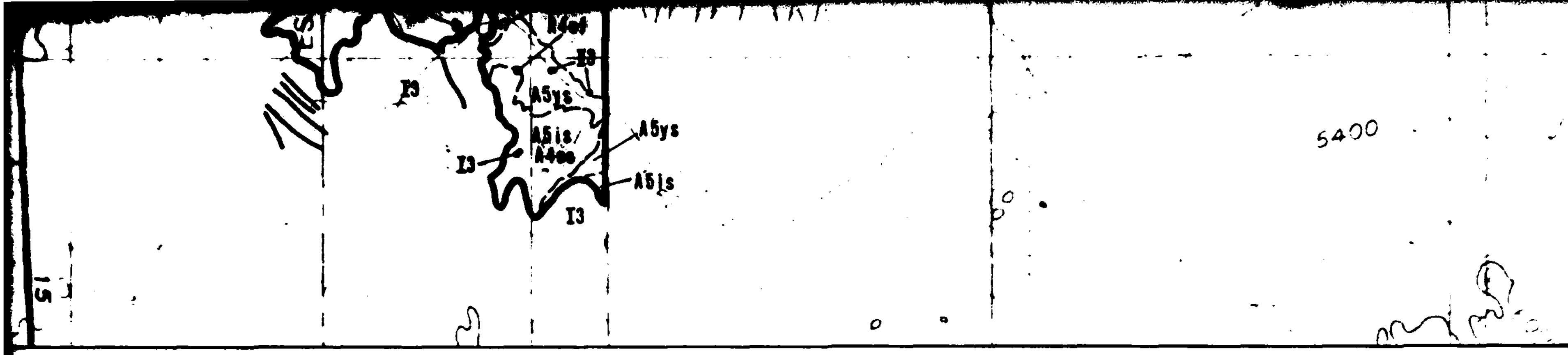
DRAWING
3-1

FUGRO NATIONAL, INC.



MOUNTAIN
RHYOLITE PEAK
BLACK MTN
BOOKER MTN
Tonopah
MT ODDIE
Radio towers
Silver Peak Mine
McKinney Tanks
A5is
A5ys
A5ys/A3d
A1s
A5is (I2)
A5is (I3)
I2
I3
Water
Ruins


ARARAT
MT OCOTE
Tonopah
Racetrack
Beacon
Tonopah
5446
Silver King Mine
MONITOR PEAK
RALSTON
VALLEY
HILLS
A1s
A5ys
A5ys/A4f
A1s/A4f
A4os
A5is
A6is
A3s/A5ys
A3d/A4f
A3d
A4f
A5ys/A4of
A3s (S2/S3/I3)
A3s/A5ys (S2, S3)
I2
I3
I4
5400
1
2



EXPLANATION

SURFICIAL BASIN-FILL DEPOSITS

A1f / **A1s** Younger Fluvial Deposits - Modern stream channel and flood-plain deposits of A1f, sandy silt (ML) and A1s, silty sand (SM).

A3d / **A3s** Eolian Deposits - Wind-blown deposits of sand occurring as either dunes, A3d, gravelly sand (SP), or thin sheets, A3s, silty sand (SP). Modifying grain sizes are of minor percentage.

A4f Younger Playa Deposits - Active playa deposits of A4f, sandy clay (SC, CL), silt (ML), and clay (CL).

A4of / **A4os** Older Playa and Lacustrine Deposits - Inactive playa and older lake bed deposits of A4of, silt (ML), and clay (CL), and A4os, silty sand (SM).

A5ys Younger Alluvial Fan Deposits - Active younger alluvial fan deposits of A5ys, gravelly sand (SP), and silty sand (SM).

A5is Intermediate Alluvial Fan Deposits - Inactive intermediate-age alluvial fan deposits of A5is, gravelly sand (SP), and silty and clayey sands (SM, SC).

A5os Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits of A5os, silty sand with gravel (SM).

ROCK UNITS

Igneous (I)

I2 Rhyolite, latite, dac'te, andesite.

I3 Basalt.

I4 Ash, tuff, welded tuff, agglomerate.

3

A5ys	**Younger Alluvial Fan Deposits** - Active younger alluvial fan deposits of A5ys, gravelly sand (SP), and silty sand (SM).
A5is	**Intermediate Alluvial Fan Deposits** - Inactive intermediate-age alluvial fan deposits of A5is, gravelly sand (SP), and silty and clayey sands (SM, SC).
A5os	**Older Alluvial Fan Deposits** - Older, highly eroded alluvial fan deposits of A5os, silty sand with gravel (SM).

ROCK UNITS

Igneous (I)

I2	Rhyolite, latite, dacite, andesite.
I3	Basalt.
I4	Ash, tuff, welded tuff, agglomerate.

Sedimentary (S)

S2	Limestone with significant amounts of interbedded siltstone, shale and chert.
S3	Shale, siltstone.

A4os/A4of Combination of geologic unit symbols indicates a mixture of either surficial basin-fill deposits or rock units inseparable at map scale.

A5os (I2) Parenthetic unit underlies surface unit at shallow depth.

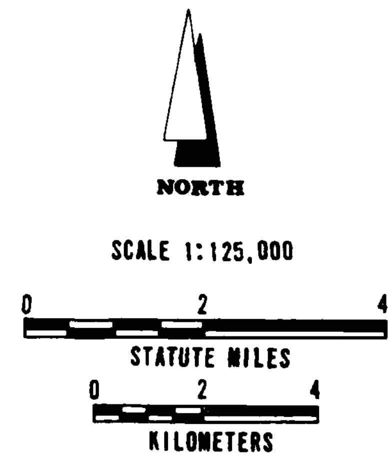
SYMBOLS

Contact between rock and basin fill (and northern and southern valley boundaries).

Contact between surficial basin fill or rock units.

Fault, dashed where approximately located.

Photo lineament, possibly fault related.

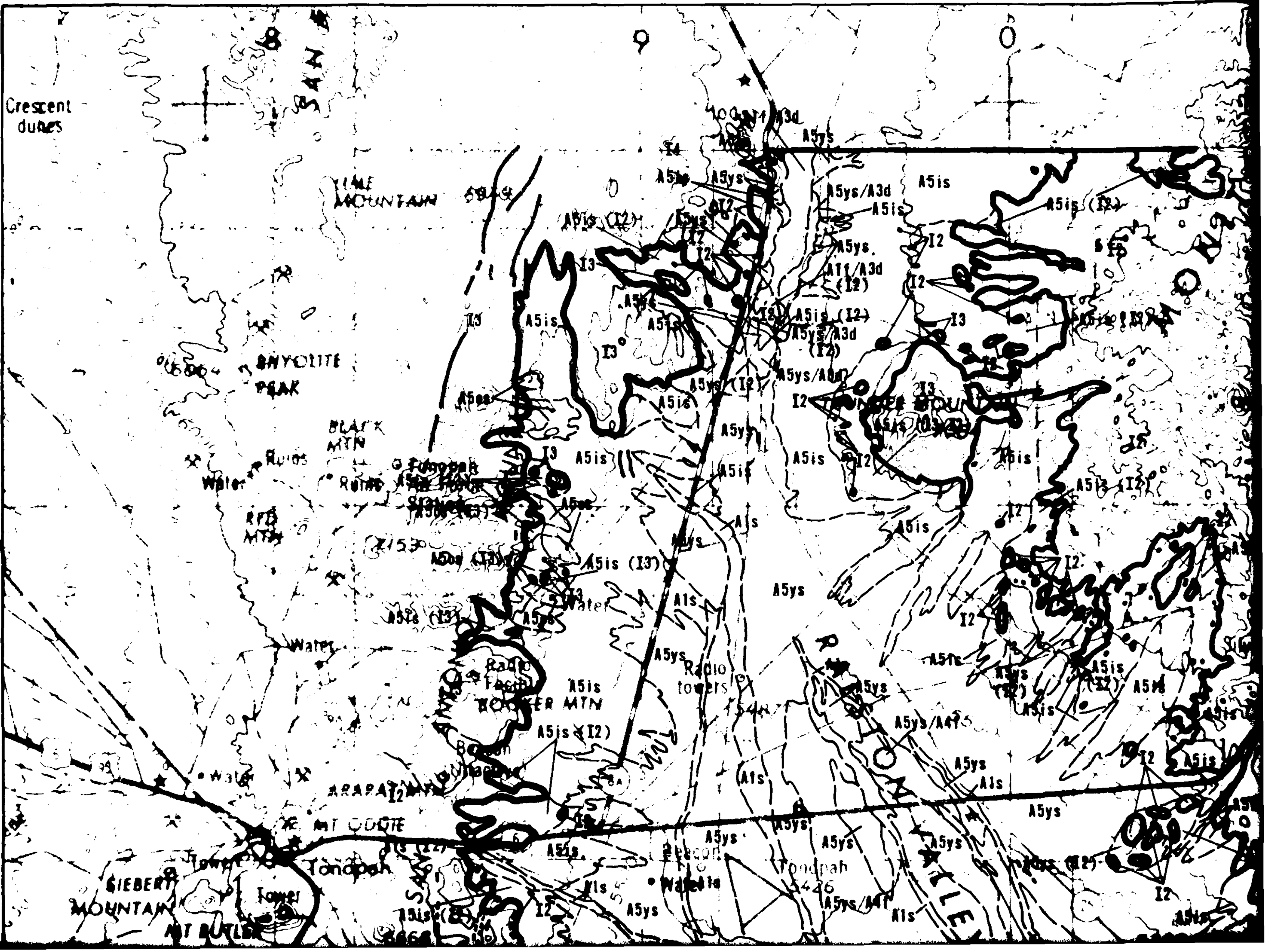


4

NOTES:

1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II, Drawing II-1-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II, Section 1.0.

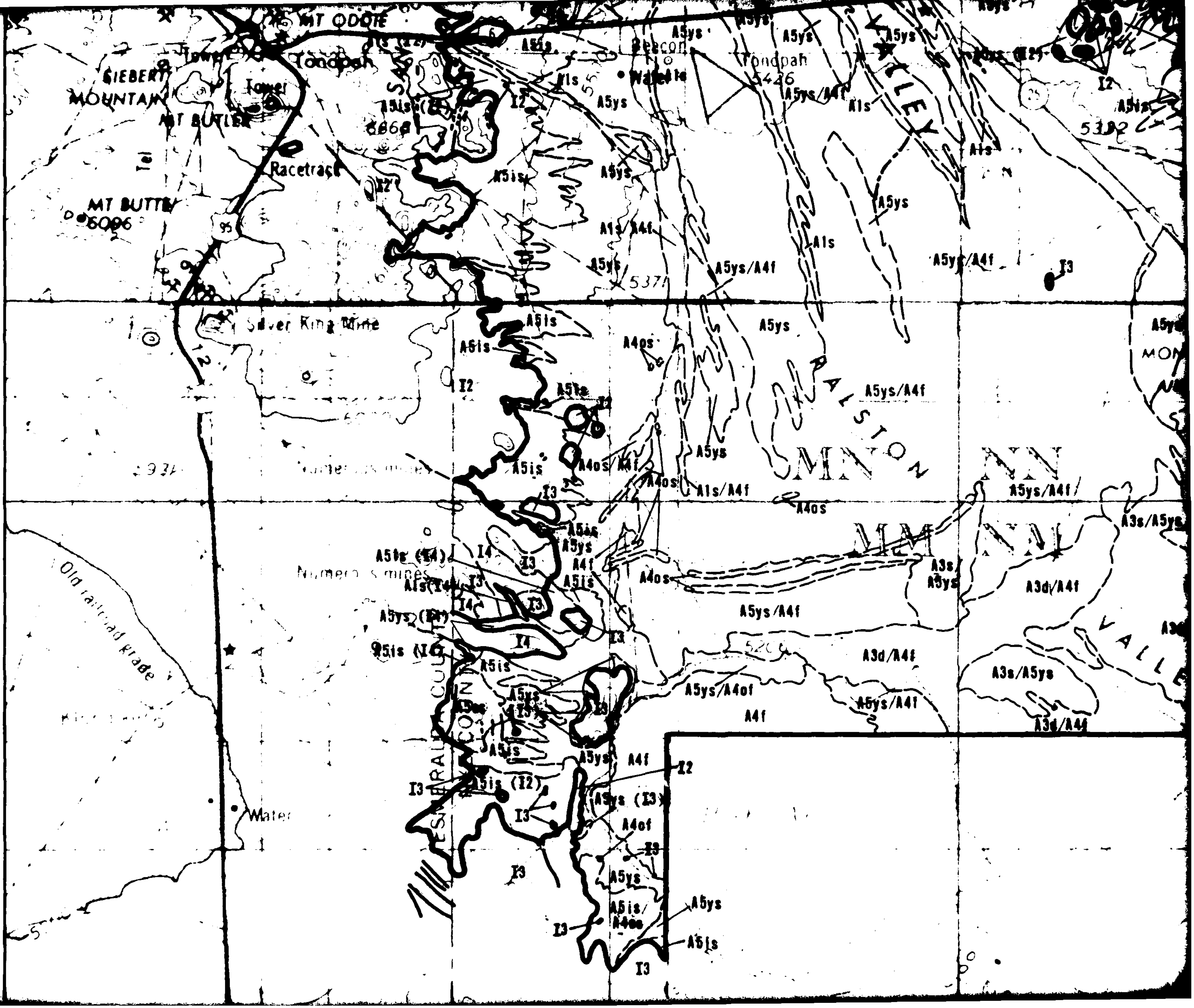
15 JUN 88



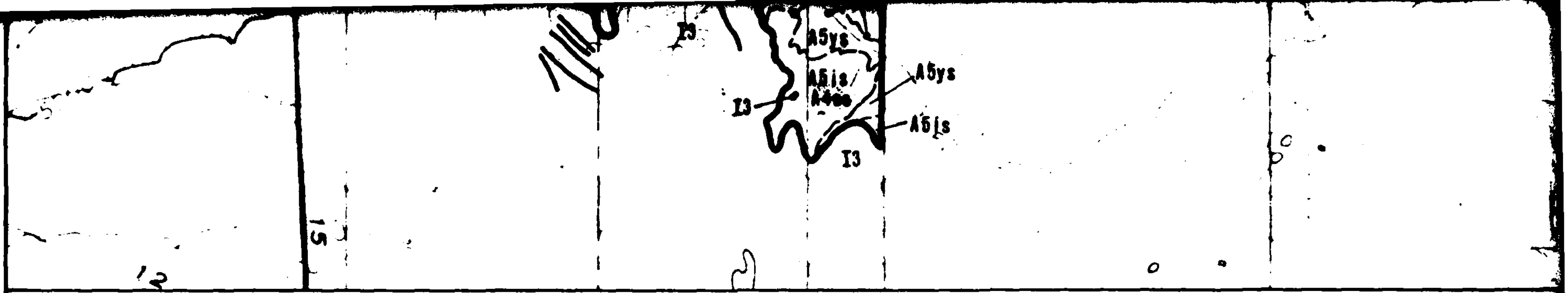
Crescent dunes
LIME MOUNTAIN
RHYOLITE PEAK
BLACK MTN
Ruins
Water
Radio towers
A5is
A5ys
A5ys/A3d
A1s
I2
I3
A5is (I2)
A5is (I3)
Tonopah
Tower
SIEBERT MOUNTAIN
MT BUTLER
MT OODIE
A5ys/A4f
Tonopah 5426

1

6.



MT ODDIE
Tonopah
SIEBERT MOUNTAIN
Tower
MT BUTLER
Racetrack
MT BUTLER
6086
95
Silver King Mine
Beacon
Tonopah
5426
VALLEY
5392
RALSTON
MTN
MONTEZUMA
VALLEY
Numerous mines
ESMERALDA COUNTY
Old railroad grade
Water
A5ys
A5is
A1s
A5ys/A4f
A1s/A4f
A4os
A4os/A4f
A5ys/A4of
A3s/A5ys
A3d/A4f
A4f
A4of
I2
I3
I4



EXPLANATION

SURFICIAL BASIN-FILL DEPOSITS

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A5is	Intermediate Alluvial Fan Deposits - Inactive intermediate-age alluvial fan deposits of A5is, gravelly sand (SP), and silty and clayey sands (SM, SC).
A5os	Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits of A5os, silty sand with gravel (SM).

ROCK UNITS

Igneous (I)

I2	Rhyolite, latite, dacite, andesite.
I3	Basalt.
I4	Ash, tuff, welded tuff, agglomerate.

Sedimentary (S)

A5ys	Younger Alluvial Fan Deposits - Active younger alluvial fan deposits of A5ys, gravelly sand (SP), and silty sand (SM).
A5is	Intermediate Alluvial Fan Deposits - Inactive intermediate-age alluvial fan deposits of A5is, gravelly sand (SP), and silty and clayey sands (SM, SC).
A5os	Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits of A5os, silty sand with gravel (SM).

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I3	Basalt.
I4	Ash, tuff, welded tuff, agglomerate.

Sedimentary (S)

S2	Limestone with significant amounts of interbedded siltstone, shale and chert.
S3	Shale, siltstone.

A4os/A4of Combination of geologic unit symbols indicates a mixture of either surficial basin-fill deposits or rock units inseparable at map scale.

A5os (I2) Parenthetic unit underlies surface unit at shallow depth.

SYMBOLS

- Contact between rock and basin fill (and northern and southern valley boundaries).
- Contact between surficial basin fill or rock units.
- Fault, dashed where approximately located.
- Photo lineament, possibly fault related.

NOTES:

1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II, Drawing II-3-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II, Section 1.0.

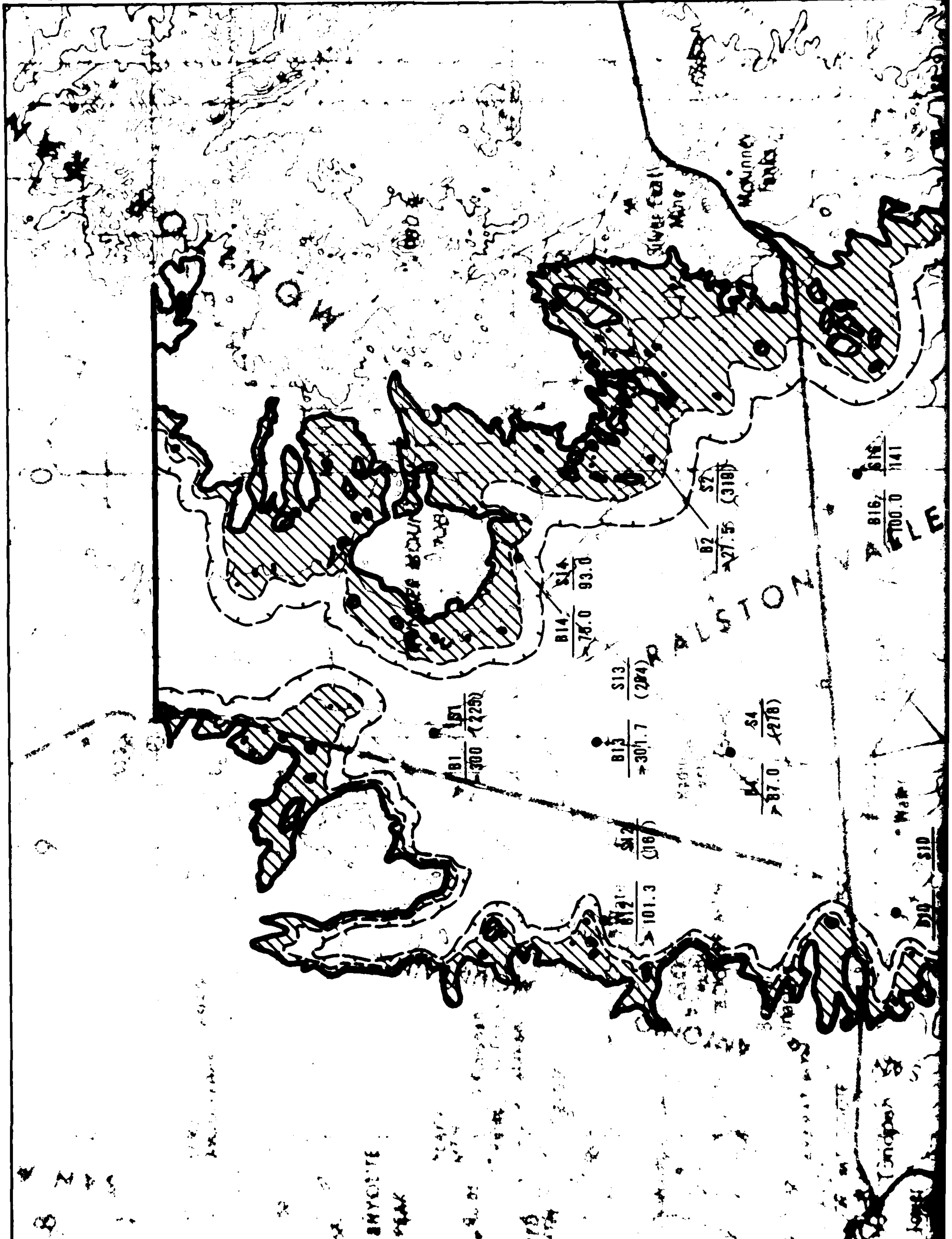
SURFICIAL GEOLOGIC UNITS
RALSTON VALLEY, NEVADA

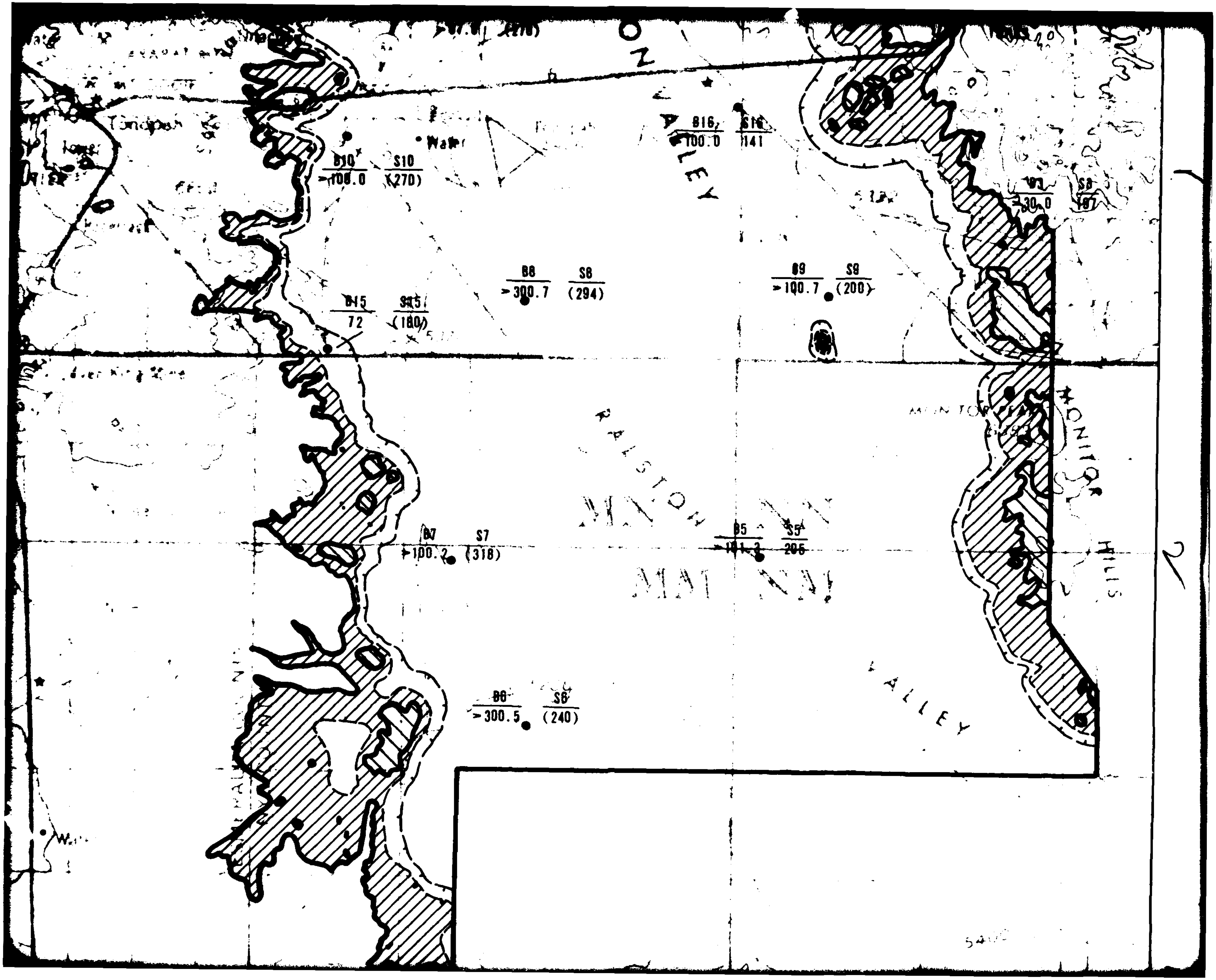
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING 3-2

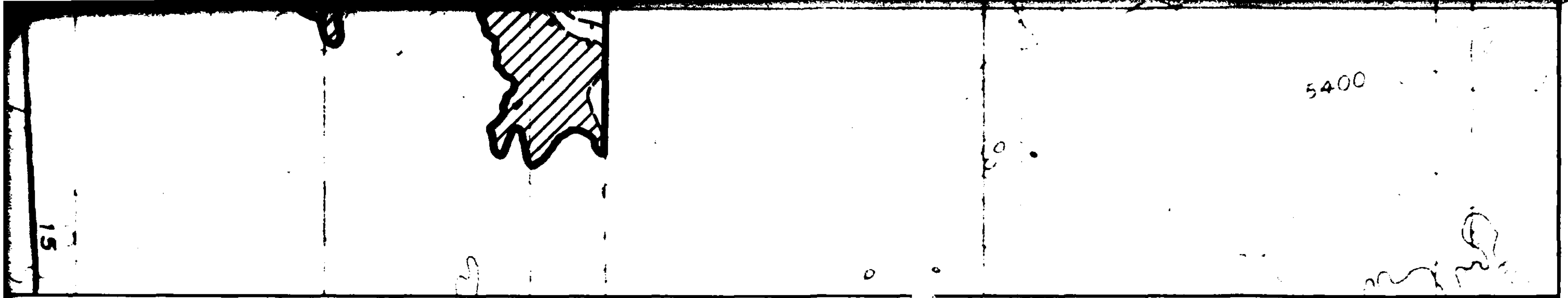
FUGRO NATIONAL, INC.

8


RALSTON
Silver Bell Mine
McKinney Tanks
B1
300
S1
(225)
B13
>301.7
S13
(284)
B14
76.0
S14
93.0
B2
27.5
S2
(318)
S4
(278)
B4
87.0
B12
101.3
S12
(16)
B16
100.0
S16
1141
B10
S10



RALSTON
VALLEY
MONITOR HILLS
Tonopah
Water
B16 / >100.0
S16 / 141
B10 / >100.0
S10 / (270)
B8 / >300.7
S8 / (294)
B9 / >100.7
S9 / (200)
B15 / 72
S15 / (180)
B7 / >100.2
S7 / (318)
B5
S5 / 205
B6 / >300.5
S6 / (240)
S8 / 197
30.0
2



EXPLANATION

50 — Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m).

150 — Contour indicates rock at a depth of approximately 150 feet (46m) - hachuring indicates rock less than 150 feet (46m).

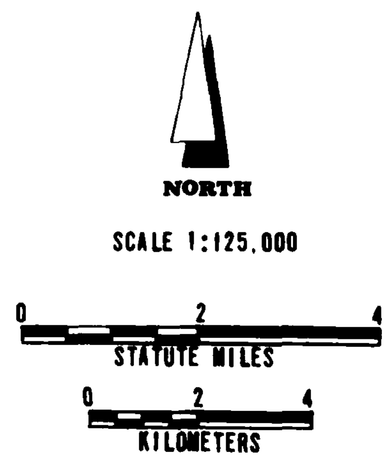
Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.

● S4/75 — Data Source - Fugro boring (B); seismic refraction line (S); electrical resistivity sounding (R); or water well (W); Volume II, Table 2-1.

Depth to rock (feet) or, when in parentheses, depth above which rock does not occur (feet).

NOTE: The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained. Seismic depth to rock values at S-3, and S-16 interpreted to correspond to top of Paleozoic basement rock, and fluvial/alluvial gravels, respectively.



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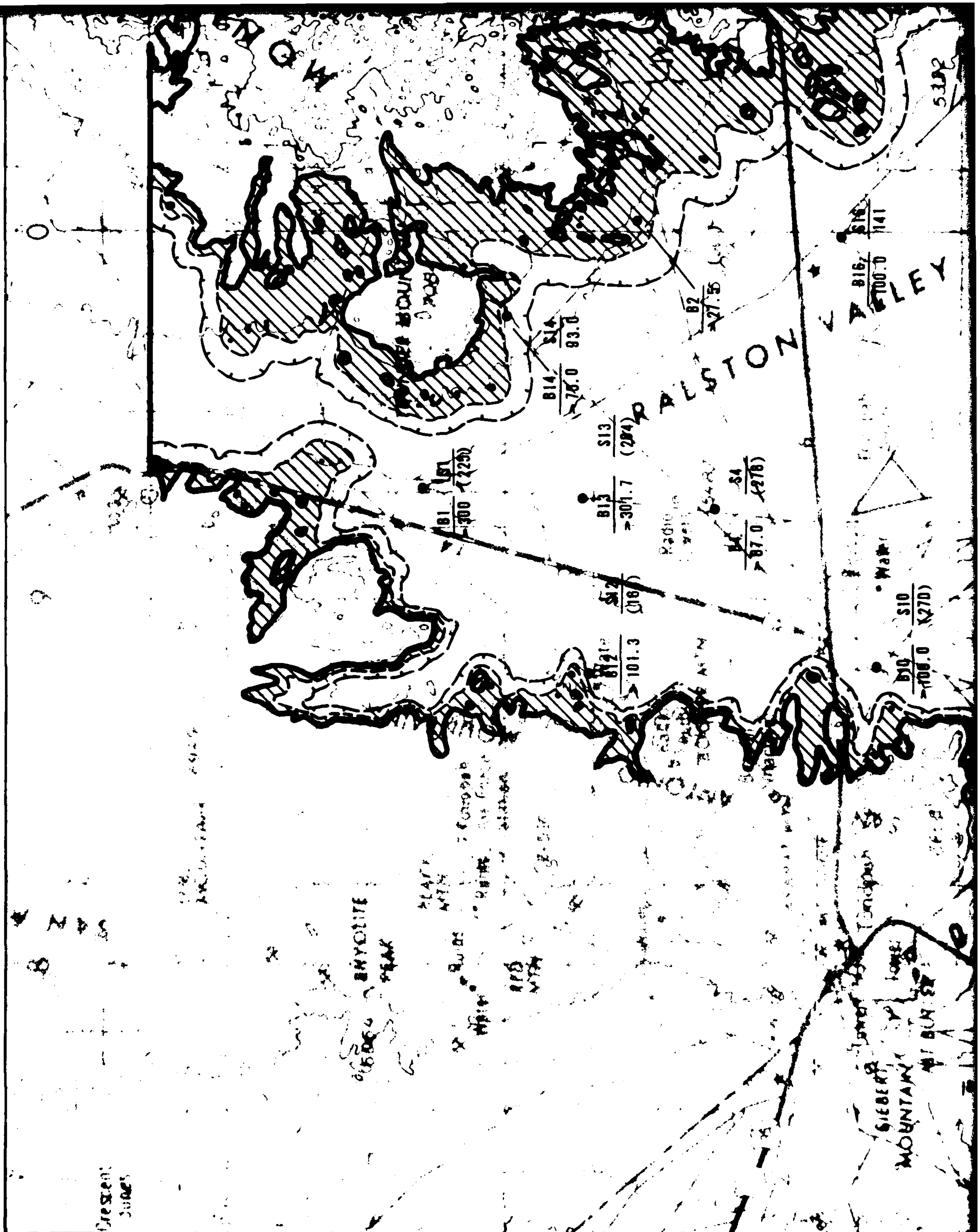
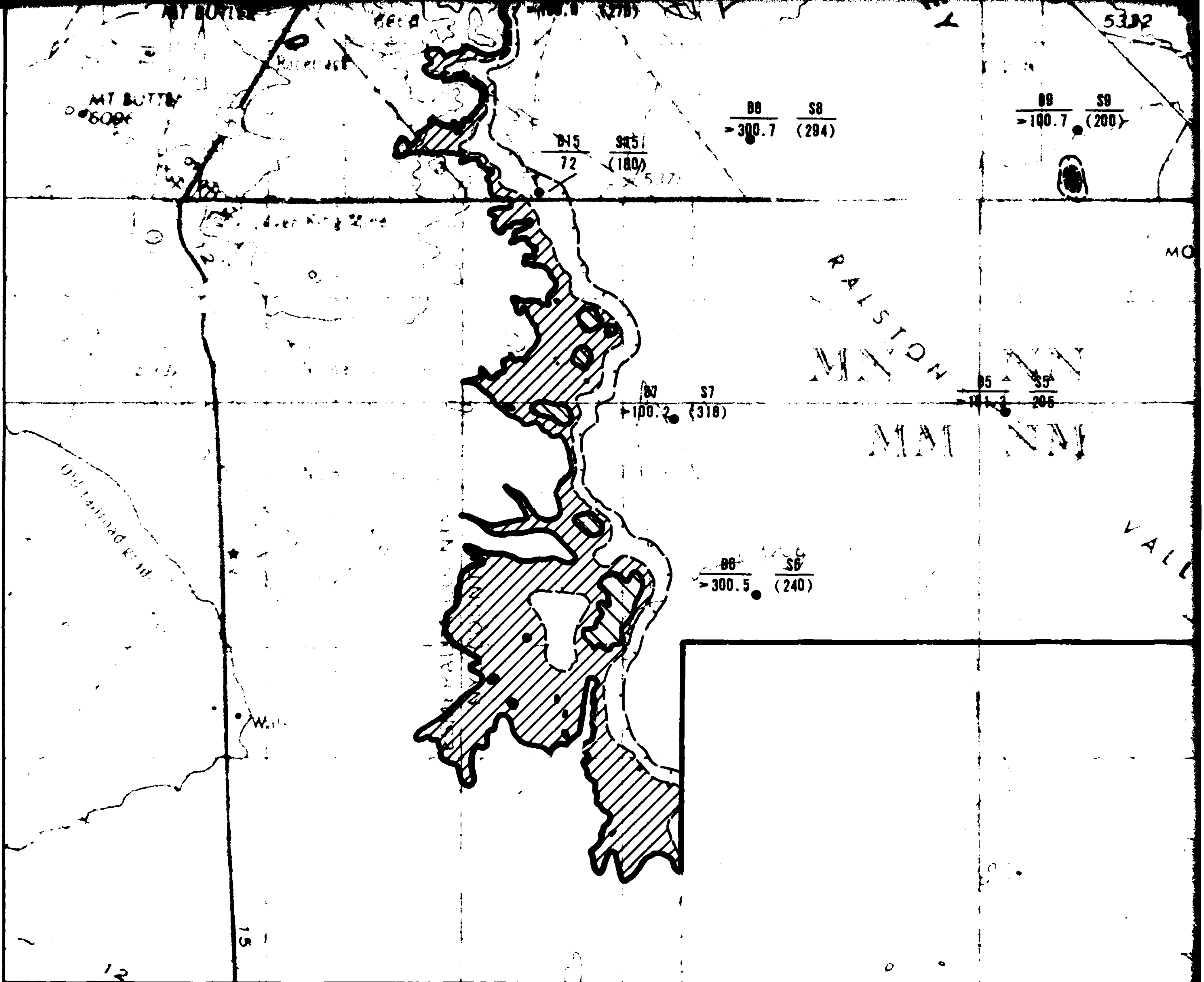


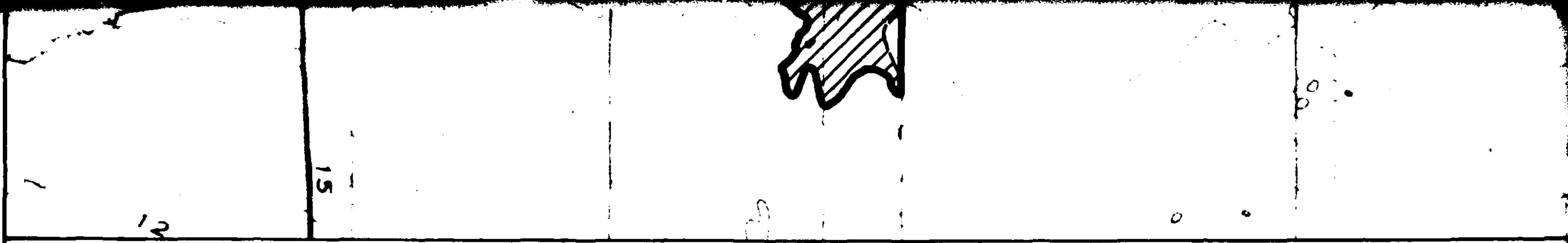
RALSTON VALLEY
B14 / 76.0
S14 / 93.0
B2 / >27.5
B16 / 100.0
S16 / 1141
B1 / >300
S1 / (225)
B13 / >301.7
S13 / (204)
S4 / (278)
B4 / >87.0
B12 / >101.3
B10 / >100.0
S10 / (270)
RHYOLITE PEAK
SIEBERT MOUNTAIN
Crescent Dunes

15 JUN 80



MT BUTTE
B15
72
S15
(180)
B8
>300.7
S8
(294)
B9
>100.7
S9
(200)
RALSTON
B7
>100.2
S7
(318)
B5
S5
205
B6
>300.5
S6
(240)
15
12

5



EXPLANATION

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150 — Contour indicates rock at a depth of approximately 150 feet (46m) - hachuring indicates rock less than 150 feet (46m).

Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.

● $\frac{S4}{75}$ Data Source - Fugro boring (B); seismic refraction line (S); electrical resistivity sounding (R); or water well (W); Volume II, Table 2-1.

Depth to rock (feet) or, when in parentheses, depth above which rock does not occur (feet).

NOTE: The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained. Seismic depth to rock values at S-3, and S-16 interpreted to correspond to top of Paleozoic basement rock, and fluvial/alluvial gravels, respectively.

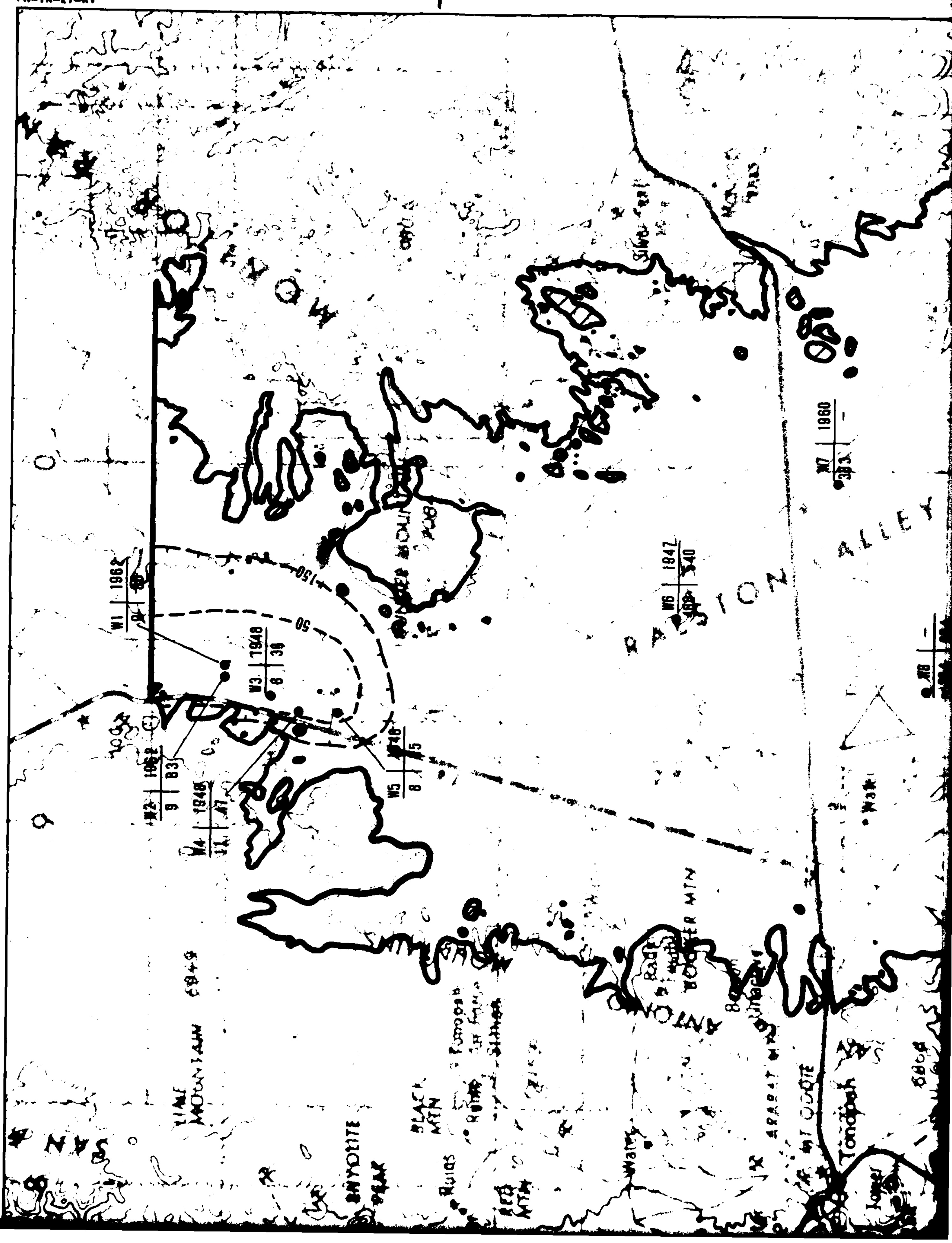
DEPTH TO ROCK
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

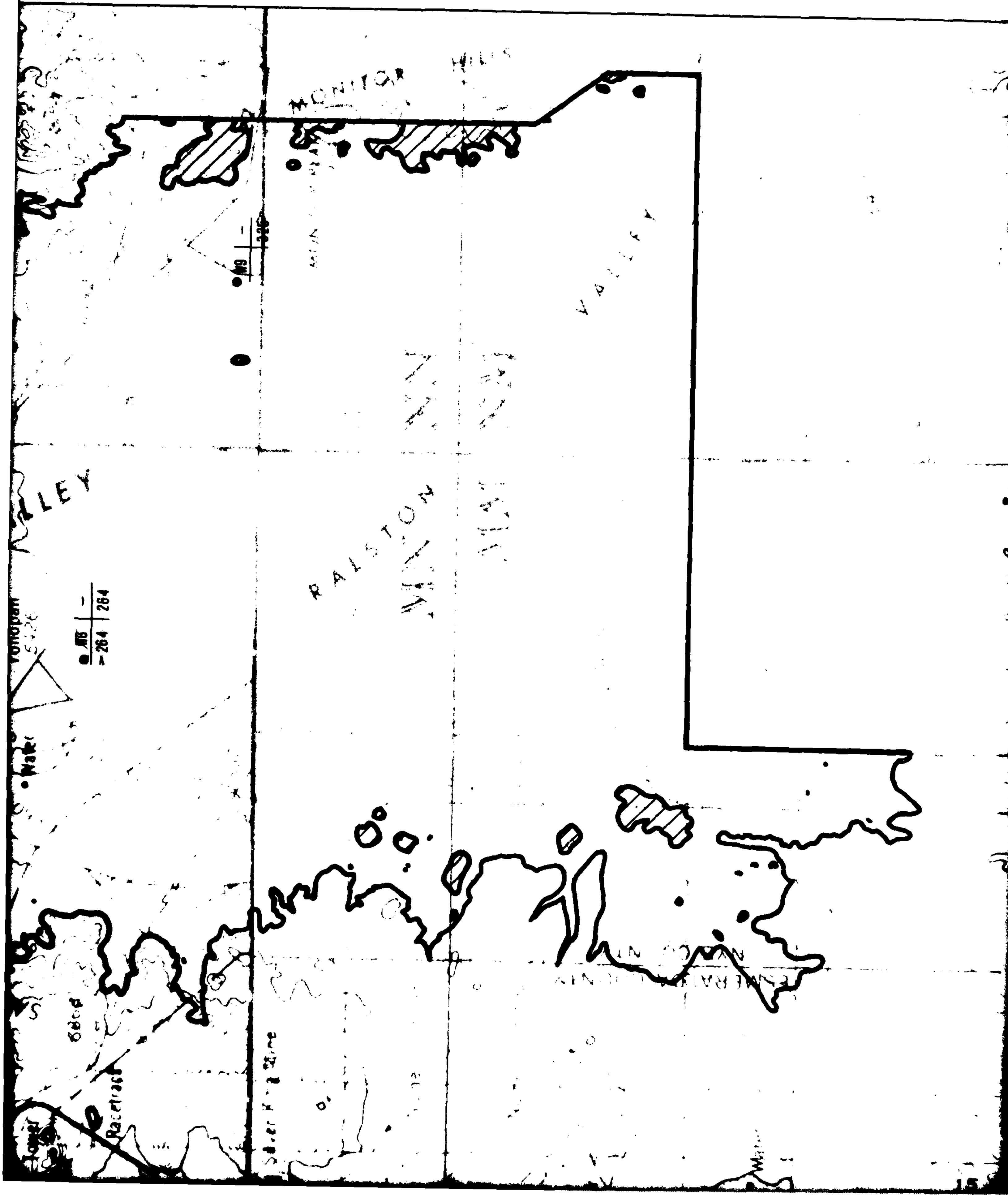
DRAWING
3-3

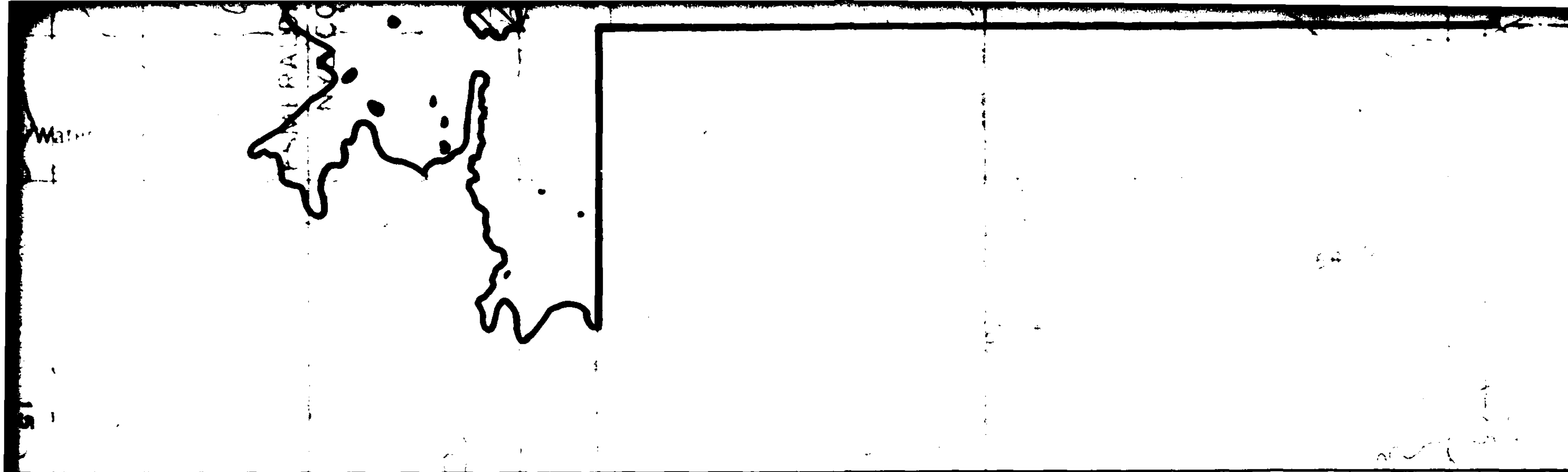
FUGRO NATIONAL, INC.

6


W1 1962
W3 1948
W6 1947
W7 1960
-150-
-50-
LIME MOUNTAIN
BLACK MTN
RHYOLITE PEAK
Ruins
Tonopah

1 2





EXPLANATION

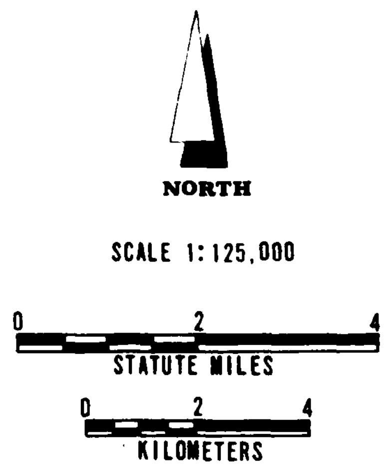
Limited extent of contours indicates ground water occurs at depths greater than 150 feet in most of the valley. Fugro National, Inc. borings and assorted wells indicate depth to ground water generally in excess of 200 feet throughout most of the valley (see Volume I, Section 3.0).

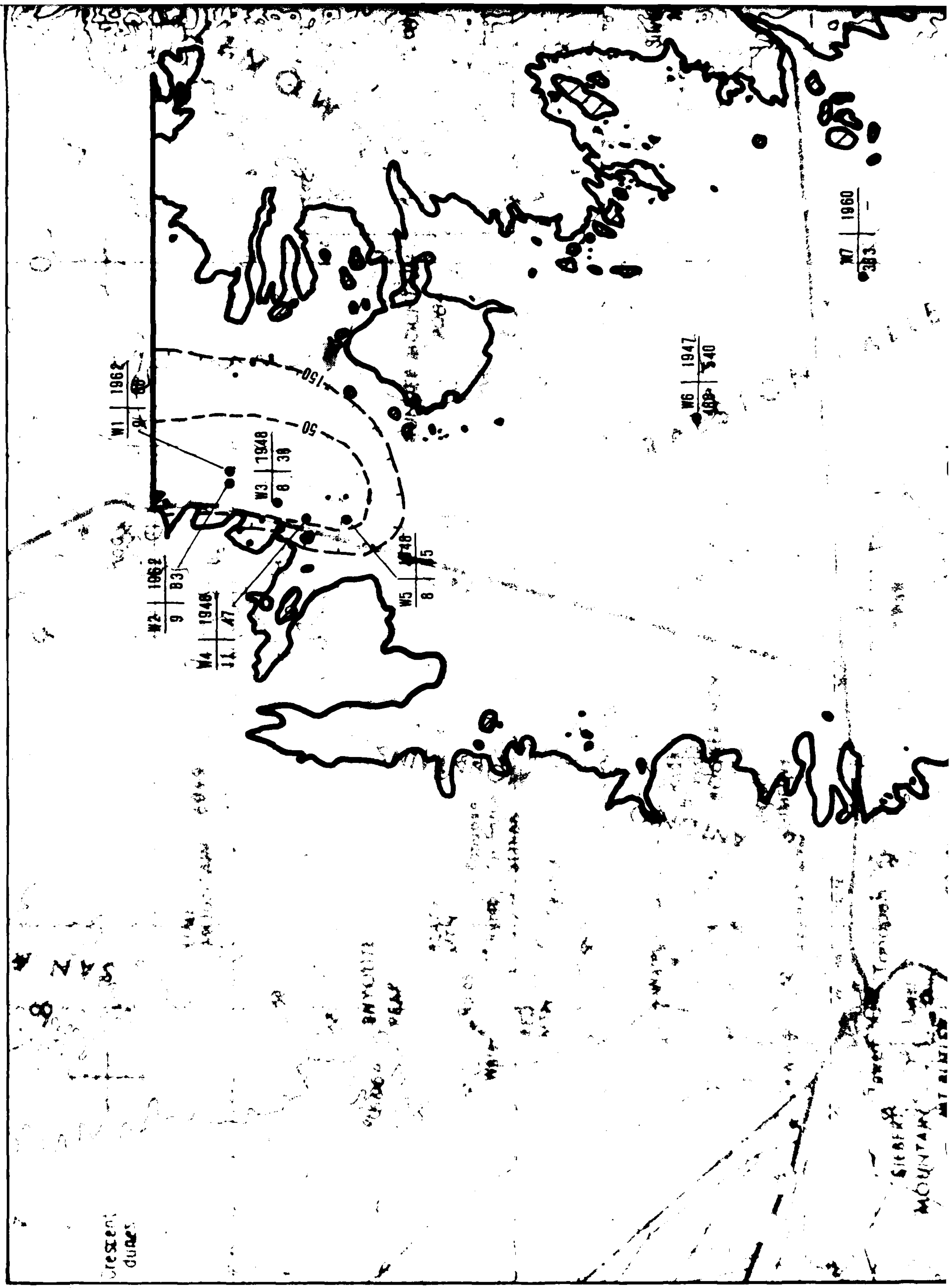
Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.

● W1 | 1977 / 150 | 700

Data Source – Fugro boring (B); seismic refraction line (S); electrical resistivity sounding (R); or water well (W), see Volume II, Table 2-1.	Year of water level measurement
Depth to water (feet)	Depth of well (feet)

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W2 1962 9 83
W3 1948 8 38
W4 1948 47
W5 8
W6 1947
W7 1960 383
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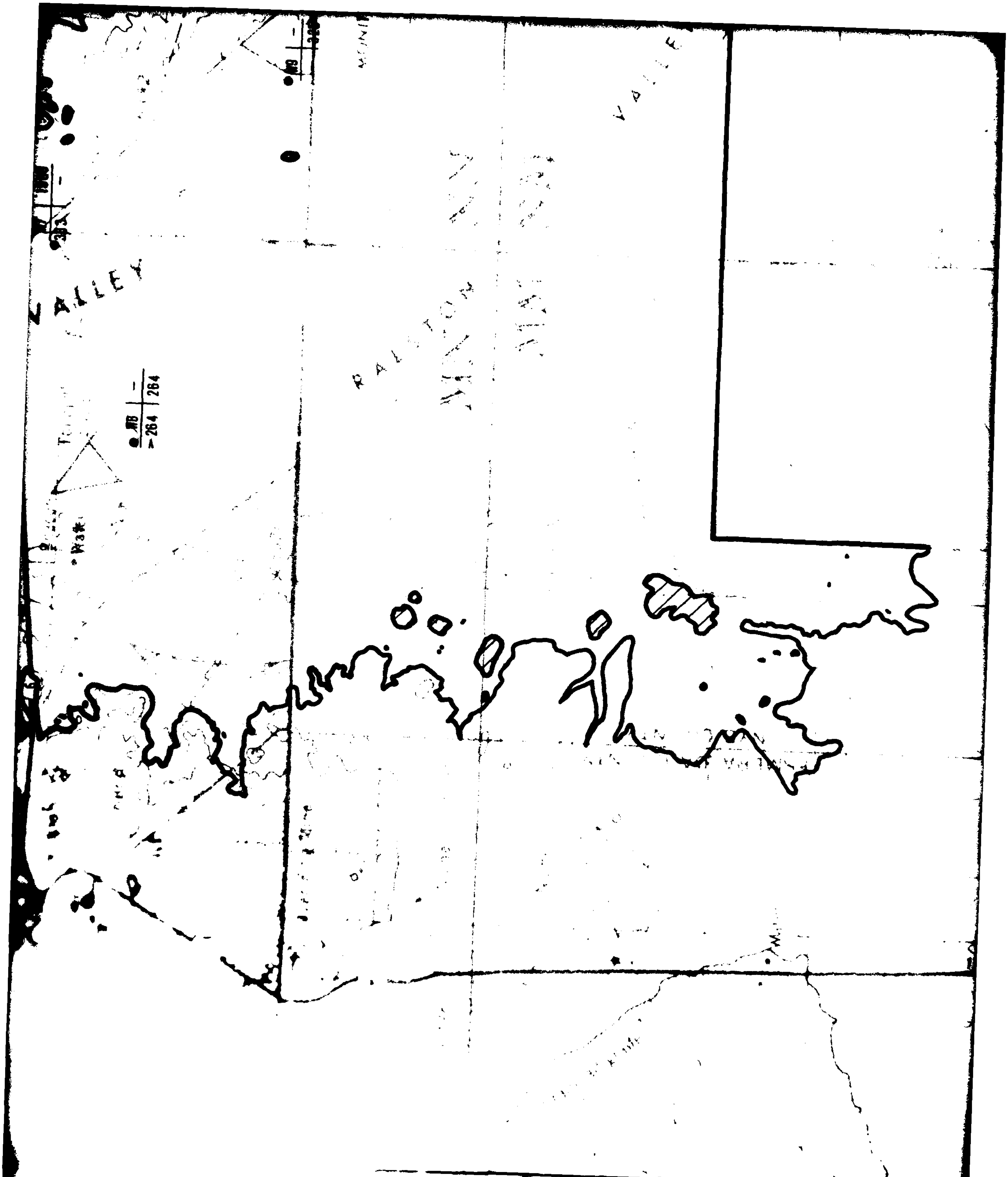

VALLEY
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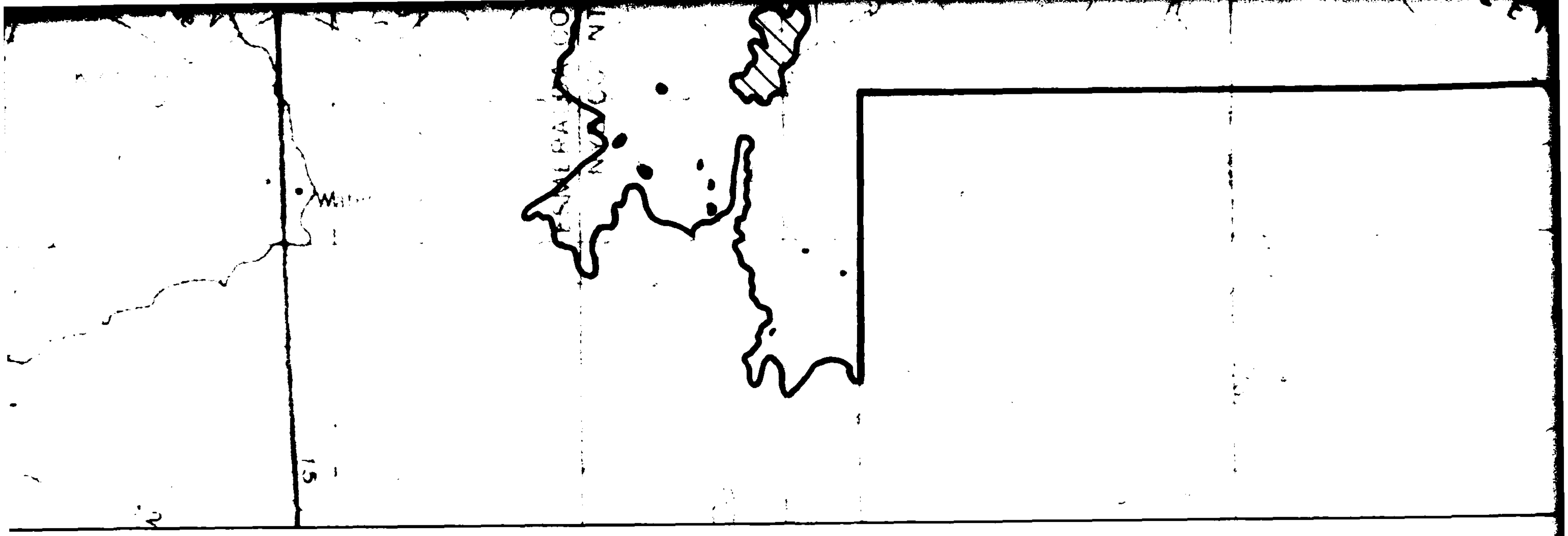

EXPLANATION

Limited extent of contours indicates ground water occurs at depths greater than 150 feet in most of the valley. Fugro National, Inc. borings and assorted wells indicate depth to ground water generally in excess of 200 feet throughout most of the valley (see Volume I, Section 3.0).

Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.

W1 | 1977 / 150 | 700	Data Source - Fugro boring (B); seismic refraction line (S); electrical resistivity sounding (R); or water well (W), see Volume II, Table 2-1.	Year of water level measurement
	Depth to water (feet)	Depth of well (feet)

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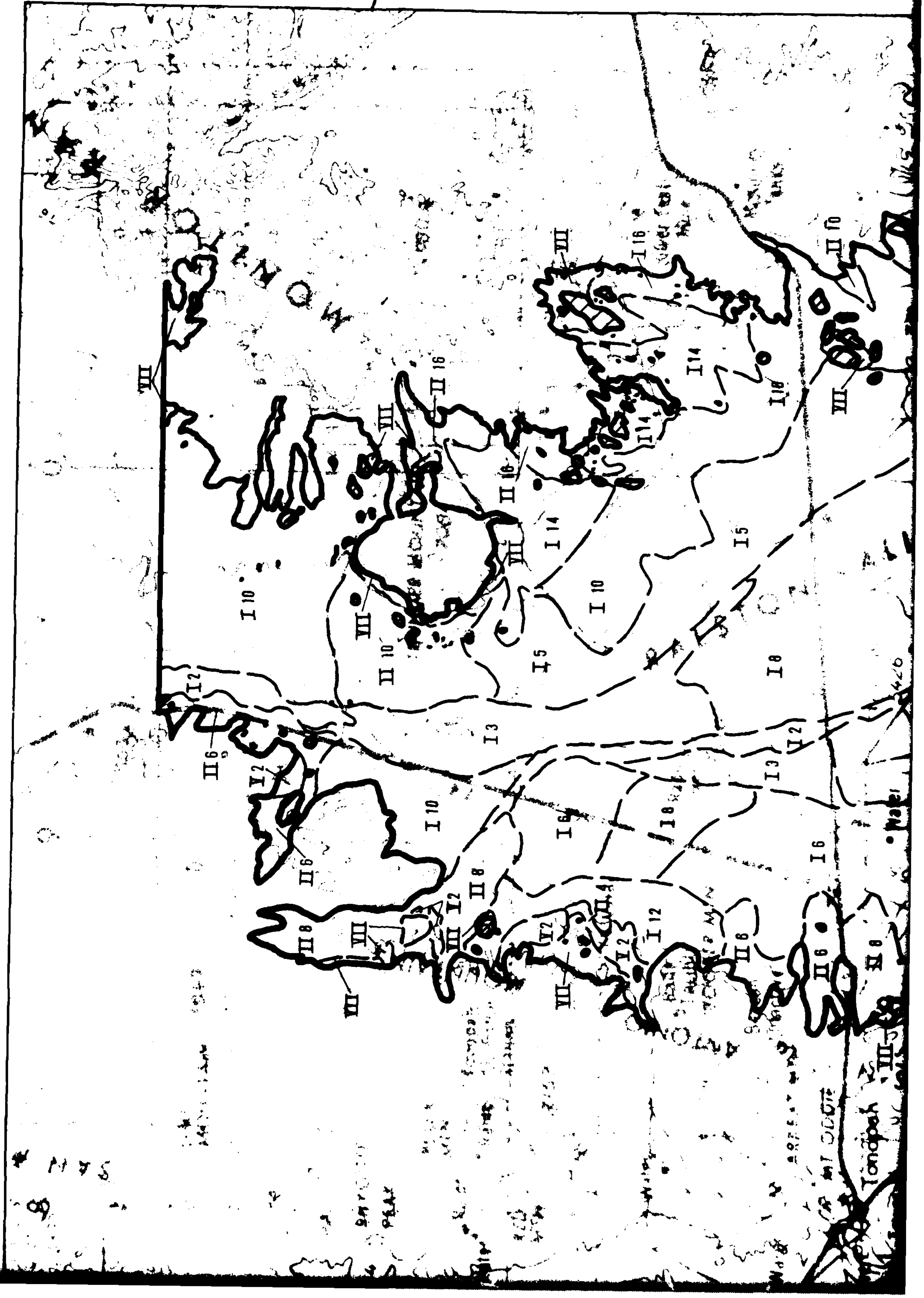
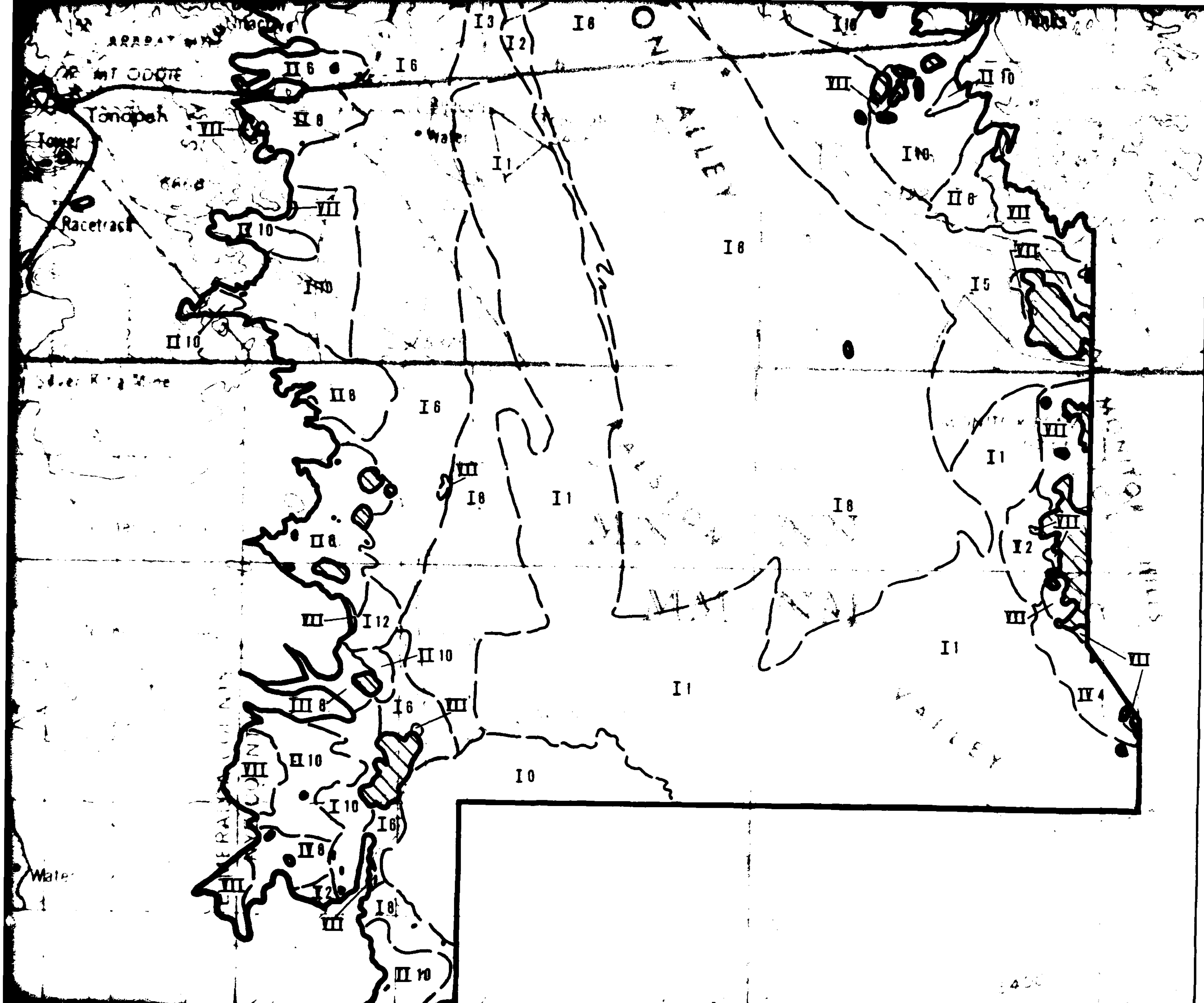
DEPTH TO WATER
RALSTON VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING 3-4

FUGRO NATIONAL, INC.


Tonopah



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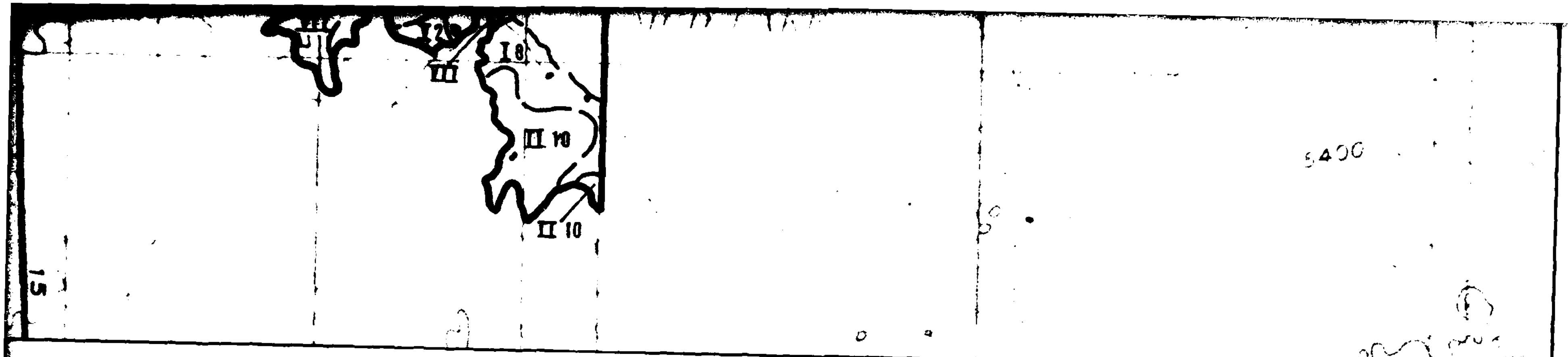


EXPLANATION

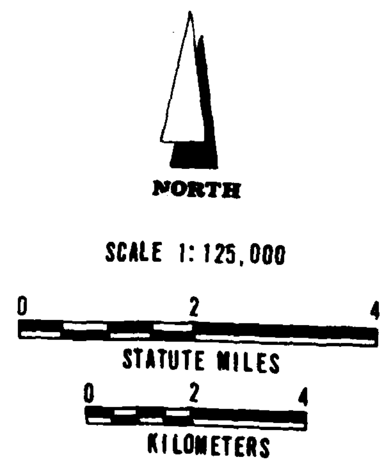
Terrain Category (see table below) — III - 3 — Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).

TERRAIN CATEGORY	DRAINAGE DEPTH DESCRIPTION
I	Less than 3 feet (1m)
II	3-6 feet (1-2m)
III	6-10 feet (2-3m)
IV	10-15 feet (3-5m)
V	Greater than 15 feet (5m).
VI	Complex, highly variable terrain not defined by drainage incision (e.g. dunal or hummocky terrain).
VII	Unsuitable terrain

Contact between terrain categories.

Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.



NOTE: Data used in constructing this map are from: (1) field observations,

EXPLANATION

Terrain Category — — — III - 3 — — — Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).
(see table below)

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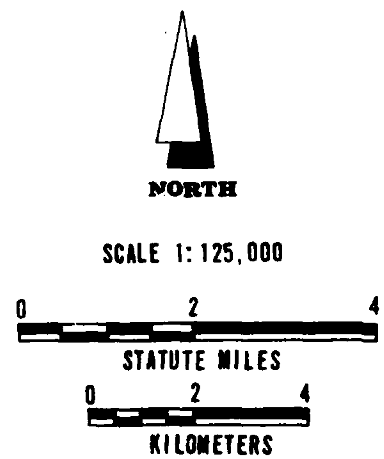
VII	Unsuitable terrain

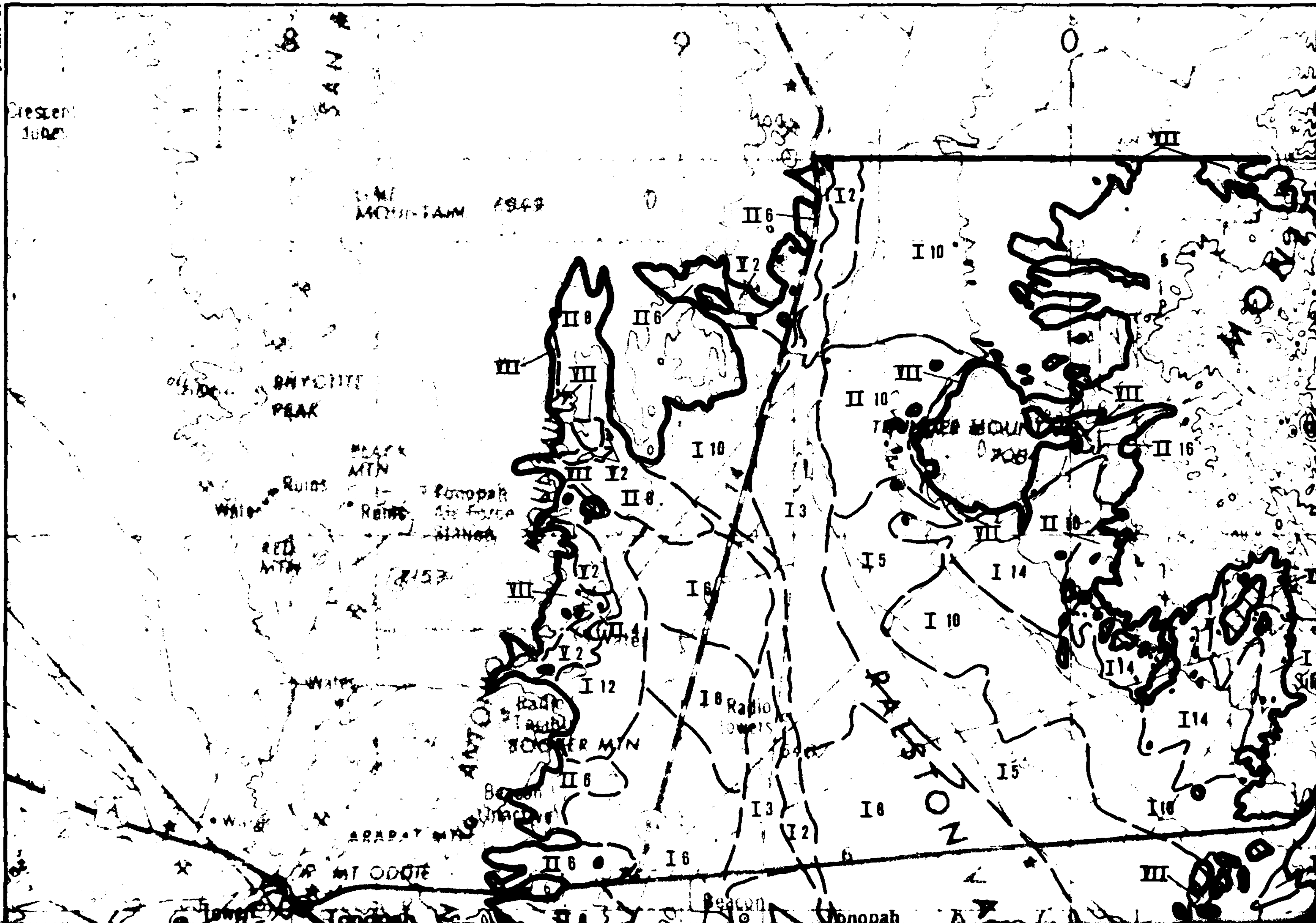
Contact between terrain categories.

Contact between rock and basin fill (and *northern* and *southern* valley boundaries).

Shading indicates areas of isolated exposed rock.



NOTE: *Data used in constructing this map are from: (1) field observations, (2) 1:62,500 USGS topographic maps, and (3) 1:60,000 and 1:25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.*



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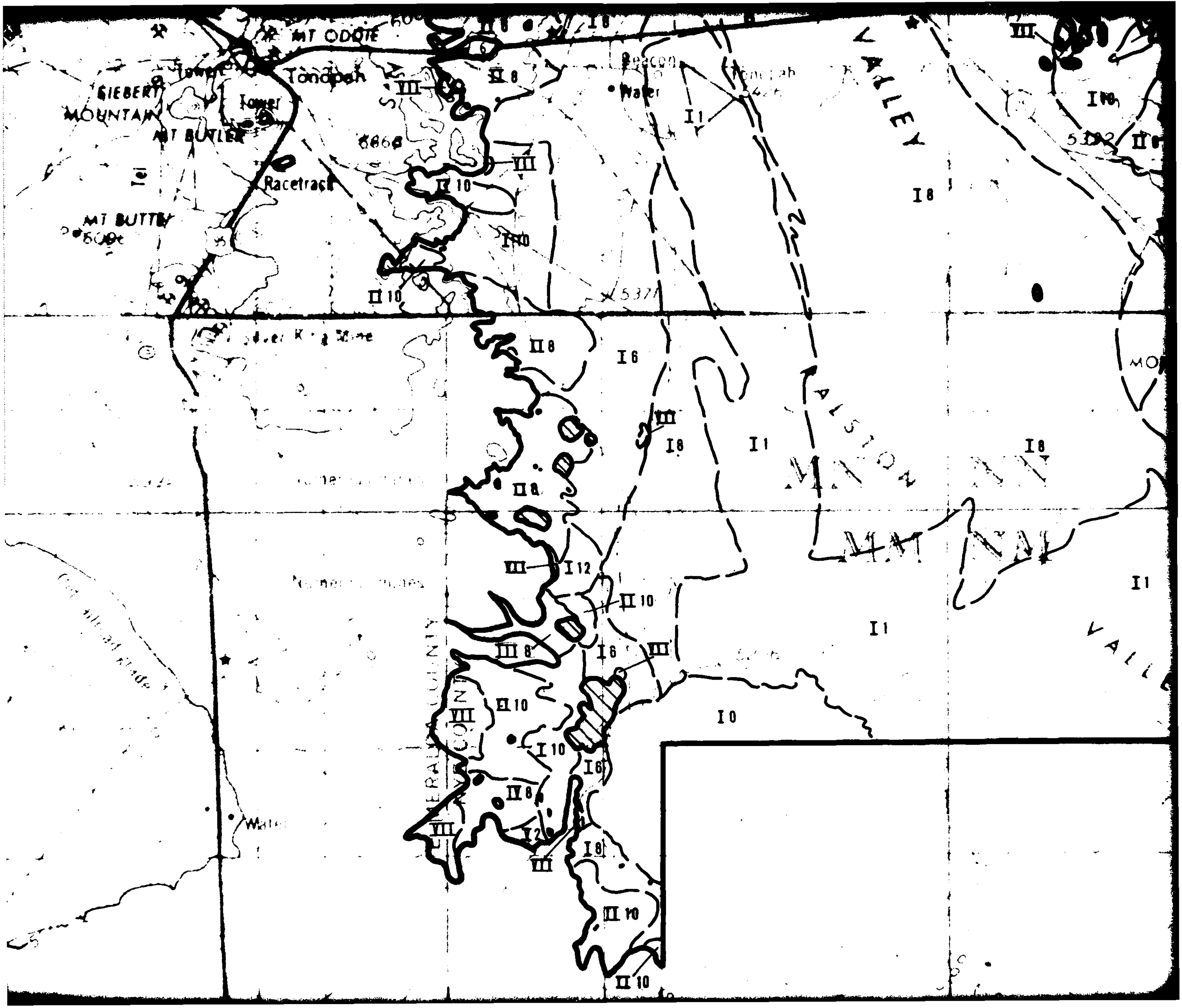

MT ODDIE
Tonopah
SIEBERT MOUNTAIN
MT BUTLER
Racetrack
MT BUTTE
Beacon
Water
VALLEY
RALSTON
Silver King Mine

EXPLANATION

Terrain Category — III - 3 — Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).
(see table below)

TERRAIN CATEGORY	DRAINAGE DEPTH DESCRIPTION
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Contact between terrain categories.

Contact between rock and basin fill (and northern and southern valley boundaries).

Shading indicates areas of isolated exposed rock.

NOTE: *Data used in constructing this map are from: (1) field observations,* (2) 1:62,500 USGS topographic maps, and (3) 1:60,000 and 1:25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.

TERRAIN
RALSTON VALLEY, NEVADA

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DRAWING 3-5

FUGRO NATIONAL, INC.

7

APPENDIX

APPENDIX

Table of Contents

APPENDIX

Table of Contents (cont.)

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 11,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a lineup of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of moisture content through which a soil-water mixture is plastic.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BASE LEVEL - The theoretical limit or lowest level toward which erosion constantly progresses; the level at which neither erosion or deposition takes place.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated, surficial material.

BORING - A method of subsurface exploration whereby an open hole is formed in the ground through which soil-sampling or rock-drilling may be conducted.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation, and terrain corrections have been applied to gravity data.

BOULDER - A rock fragment, usually rounded by weathering and abrasion with an average diameter of 12 inches (305 mm) or more.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - Gravel, sand, or other material cemented principally by calcium carbonate.

CALIFORNIA BEARING RATIO (CBR) - Is the ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D1883-73). During the CBR test, the load is applied on the circular penetration piston (3 inches^2 base area; 19 cm^2) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/ minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1 inch (2.5 mm) penetration.

CLAY - Fine-grained soil (passes No. 200 sieve; 0.074 mm) that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air dry.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

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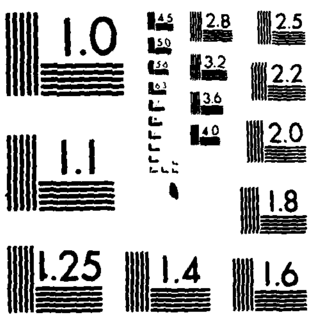

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobble) larger than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, usually rounded or subrounded with an average diameter between 3 and 12 inches (76 and 305 mm).

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).

COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.

CONDUCTIVITY - The ability of a material to conduct electrical current. In isotropic material, conductivity is the reciprocal of resistivity. Units are mhos per meter.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60° apex angle, 10-cm^2 projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally projected area.

Friction resistance, f_s - The resistance to penetraton developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DETECTOR - See GEOPHONE.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current.

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL (stream) - A stream in which water flow is discontinuous and of short duration.

EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.

EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

FAULT - A plane or zone of rock fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch-(2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pickup.

GRABEN - An elongated crustal block that has been downthrown along faults relative to the rocks on either side.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process, using a hydrometer.

GRANULAR - See Coarse-Grained.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and are retained on a No. 4 (4.75 mm sieve).

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GYPSIFEROUS - Containing gypsum, a mineral consisting mostly of sulfate of calcium.

HORST - An elongated crustal block that has been uplifted along faults relative to the rocks on either side.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in preexisting rock, (e.g., granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LARAMIDE OROGENY - A time of deformation extending from late Cretaceous (about 100 million years ago) to the end of the Paleocene (about 50 million years ago) which accounted for much present Basin and Range structure.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOW STRENGTH SURFICIAL SOIL - Soil which will perform poorly as a road subgrade, at its present consistency, when used directly beneath a road section.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the ovendry weight of the sample.

NEOTECTONICS - The study of the recent structural history of the earth's crust, usually during the late Tertiary and the Quaternary periods.

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third 6 inches (0.15 m) with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

P-WAVE - See Compressional Wave.

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action, the finer dust and sand are blown or washed

away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case, the armored surface is formed by dissolution and cementation of the grains involved.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

pH - An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration.

PHI (Ø) - Angle of internal friction.

PIEZOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch-(73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of clay, silt, or fine sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RANGE-BOUNDED FAULT - Usually a normal fault in which one side has moved up relative to the other and which separates the mountain front from the valley.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (True, Intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

S-WAVE - See Shear Wave.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See Geophone.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-wave or transverse wave.

SHEET FLOW - A process in which stormborne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing 24 geophones have been used in Fugro's seismic refraction surveys.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

SULFATE ATTACK - The process during which sulfates, salts of sulfuric acid, contained in ground water cause dissolution and damage to concrete.

SURFICIAL DEPOSIT - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.

TEST PIT - An excavation made to depths of about 5 feet (1.5 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 15 feet (4.5 m). A trench permits visual examination of soil in place and evaluation of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied, directed along the axis of the specimen called the axial load.

Consolidated-drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and was then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by a shear at constant water content.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

VALLEY FILL - See Basin-Fill Material/Basin-Fill Deposits.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

VELOCITY PROFILE - A cross section showing the distribution of material seismic velocities as a function of depth.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL GRADED - A soil is identified as well graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

American Society for Testing and Materials, 1976, Annual Book of ASTM Standards, Part 19: Philadelphia, American Soc. for Testing and Materials, [illegible] p.

Gary, M., McAfee, R., Jr., Wolf, C. L., eds., 1972, Glossary of geology: Washington, D.C., American Geol. Institute, 805 p.

Merriam, G., and Merriam, C., 1977, Webster's New Collegiate Dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic Dictionary of exploration geophysics: Tulsa, Oklahoma, Soc. of Exploration Geophysicists, 266 p.

A2.0 EXCLUSION CRITERIA

Table A2-1 lists the exclusion criteria applied during Verification Studies. Many of the criteria have not changed significantly since Coarse Screening Studies. Most geotechnical criteria have been modified to accommodate the basing mode requirements of the horizontal and vertical shelter concepts as well as increasing levels of study detail.

A3.0 ENGINEERING GEOLOGIC PROCEDURES

The principal objectives of the field geology investigation were to:

1. Delineate surficial extent of soil types and geologic units;
2. Assess terrain conditions; and
3. Make observations helpful in defining depth to rock and water.

Aerial photographs (1:60,000 black and white; 1:25,000 color) served as the base on which all mapping was done. Field activities were directed toward checking the photogeologic mapping.

Field checking consisted chiefly of collecting data about surficial soils at selected locations in order to refine contacts and define engineering characteristics of photogeologic units. At each location, observations of grain size distribution, color, clast lithology, surface soil development, and a variety of engineering parameters were recorded (see Volume II, Geotechnical Data). Observations were made in existing excavations (borrow pits, road cuts, stream cuts) or in hand-dug test pits. Interpretation of this data to determine surficial extent was accomplished by geologic reconnaissance over existing roads.

Of the parameters listed, grain size is the most important for engineering purposes and for this reason is included in the geologic unit designation. However, grain size is not readily mapped on aerial photos, and much of the field work involved determination of the extent of surficial deposits of a particular grain-size category (gravel, sand, or fine-grained).

Terrain data were also taken at geologic field stations. Drainage width and depth were estimated and predominant surface slope was measured. Slopes were measured over a distance of 100 to 150 feet (31 to 46 m) with an Abney hand level. For additional data, depths of major drainages encountered during geologic reconnaissance between stations were recorded on the aerial photographs.

In order to help refine depth to rock interpretations, observations were concentrated along the basin margin to identify areas of shallow rock. Observations regarding depth to water were restricted to measurements in existing wells and borings.

A4.0 GEOPHYSICAL PROCEDURES

A4.1 SEISMIC REFRACTION SURVEYS

A4.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shotpoint to recording system via an FM radio link.

The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A4.1.2 Field Procedures

"Shallow" seismic refraction lines consisted of a single spread of 24 geophones with 25 feet between geophones. Five shots were made into each spread. Shot points were located 300 feet and 10 feet from both ends of the spread and at the center of the spread. The recording system was located at the center of the spread.

"Deep" seismic refraction lines consisted of two or more spreads of 24 geophones each. The interval between geophones was 200 feet. Where spreads joined, they were overlapped by one geophone interval. In addition to shots at the end of each spread, shots were made at from one to three offset locations. The offset distances ranged from 1200 to 22,000 feet. Each time a shot was detonated, recordings were made along two adjoining spreads with two 24-trace recording systems.

The explosive used was a nitro-carbo-nitrate slurry marketed by Atlas Powder Company under the registered trade name "Aquaflo". Charge sizes ranged from as small as one pound on the "shallow" seismic lines to as large as 7080 pounds for the longest offset shots on the "deep" seismic lines. The charges were detonated using seismograph grade electric blasting caps.

Relative elevations of geophones and shotpoints within a line were measured with a transit or level.

A4.2.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal distances and best fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A4.3 DOWNHOLE SEISMIC VELOCITY SURVEYS

A4.3.1 Instruments

Downhole seismic velocity recordings were made using a SIE Model [illegible]-44 amplifier system and Model R6A oscillographic recorder. The system is capable of recording up to 24 channels of data on 6-inch (15.2-cm) wide photo-sensitive, direct write recording paper. Full width timing lines are impressed on the record at [illegible] millisecond intervals.

Mark Products Model L-10-3D-SWC downhole geophone assembly was used to detect the seismic wave arrivals in the boring. The assembly contains three mutually perpendicular geophones with natural frequency of 4.5 Hz. It is equipped with a leaf spring which maintains contact with the boring (casing) wall.

The record format included six signal traces and a "time break" trace. The amplified output of each of the three geophones was displayed at two different gain settings. The time break trace recorded the instant an electrical circuit was completed as the energy was generated. The "switch" in the circuit was formed by contact between a sledge hammer and a metallic surface which was being struck.

A4.3.2 Field Procedures

Downhole seismic travel times were obtained by mechanically generating energy at the surface and recording the arrival of the energy in a nearby boring. The horizontal separation between the boring and the point of energy generation was approximately 20 feet (6 m). The boring was cased with 3-inch (7.6-cm) diameter PVC pipe. The casing was grouted into the hole.

To begin the downhole observations, the geophone assembly was placed at a depth of 10 feet (3 m). Then seismograms (records) were obtained. Energy for the first record was generated by a sledge hammer blow downward on a metal plate lying flat on the ground. This blow generated a relatively strong compressional wave.

Energy for the second record was generated by a horizontal sledge hammer blow on a vertical metal end plate at one end of a wooden beam lying flat on the ground. The beam was oriented perpendicular to a line extending from its center to the boring.

It was coupled to the ground by having the wheels of a vehicle parked on it. A horizontal blow of this type produces shear wave energy, and relatively small compressional wave energy.

Energy for the third record was generated by striking a horizontal blow against the metal end plate at the other end of the wooden beam in order to produce shear waves with oscillatory polarity opposite to that generated for the second record.

After these three records were obtained, the geophone assembly was lowered ten feet (3 m) into the hole and three more records were obtained in the above pattern. This procedure was repeated until the bottom of the boring was reached.

A4.2.3 Data Reduction

The records were analyzed to determine the travel time between the impact and the arrival of the seismic waves at the geophone assembly. The compressional waves usually appear as a rather obvious excursion of the traces from their rest position. Except when the geophones are at shallow depths, this arrival is normally observed most readily on the traces representing the vertical geophone. The records obtained from the vertical hammer blows are the primary source of compressional wave travel time data.

The arrival of the shear wave usually occurs while the traces are still oscillating in the "wake" of the earlier arriving compressional wave. The shear wave typically causes an increase in amplitude on the trace and a lengthening of the recorded period, but the instant it arrives may be partially obscured by the compressional wave "noise". Since the shear wave is a polarized wave, the traces from the horizontal geophones on two records made with oppositely polarized energy (blows on opposite ends of the beam) are compared to note the point of phase reversal in order to assist the shear wave identification.

The wave travel times are reduced according to the ratio of the depth of the geophone in the boring and slant distance between the impact point and geophone. These reduced times are plotted on a graph of travel time versus depth. The velocity profile is interpreted by fitting straight line segments through the points. The velocity in a particular zone is indicated by the inverse slope of the line segment through that zone (slope defined as Δ time/ Δdepth).

A5.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

1. Field activities:
   - o Borings
   - o Trenches
2. Office activities:
   - o Laboratory Tests
   - o Data Analyses and Interpretations

The procedures used in the various activities are described in the following sections.

A5.1 BORINGS

A5.1.1 Drilling Techniques

The borings were drilled at designated locations using either the Becker Percussion method or rotary techniques. Specifics of these two drilling methods are discussed in the following paragraphs.

a. Becker Percussion Method: With the Becker Method, a double wall drive pipe was driven by a diesel powered pile hammer, while air was forced down the annulus of the drive pipe. The air continuously lifted the material cut by the drive bit to the surface through the center of the double wall pipe. When refusal to driving was encountered, a hydraulic rotary attachment swung into position and conventional rotary methods were used to advance the boring with the drive pipe serving as the overburden casing. Borings drilled by the truck-mounted Becker Percussion rig were nominally 5 1/2 inches (140 mm) in diameter, and ranged in depth from 25 to 100 feet (8 to 30 m).

b. Rotary Method: The borings drilled by rotary techniques used a truck-mounted Failing 1500 drill rig with hydraulic pulldown. These borings were nominally 4 7/8 inches (124 mm) in diameter. A bentonite-water slurry or compressed air was used to return soil cuttings to the surface. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils. Depths drilled ranged from 100 to 450 feet (30 to 137 m).

A5.1.2 Method of Sampling

A5.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as listed for each drilling method as well as at depths of change in soil type.

a. Becker Percussion Method:

0' to 20' (0.0 to 6.1 m)	- Bulk or Drive - samples at 5' intervals
20' to 100' (6.1 to 30.5 m)	- Bulk - samples at 10' intervals

b. Rotary Method:

0' to 30' (0.0 to 9.1 m)	- Split Spoon or Pitcher - samples at 5' intervals
30' to 100' (9.1 to 30.5 m)	- Split Spoon or Pitcher - samples at 10' intervals
100' to 300' (30.5 to 91.4 m)	- Pitcher or drive - samples at 25' intervals
300' to 450' (91.4 to 137.2 m)	- Pitcher - samples at 50' intervals

A5.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 400 pounds (181 kg) with a drop of 15 inches (38.1 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval were recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler are an outer rotating core barrel with a bit and an inner, stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the

length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Fugro Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Bulk Samples: Bulk samples were obtained from Becker Percussion drilling method by circulating the material discharged at the surface through a cyclone to reduce discharge velocity. The material was then sampled, placed in plastic bags and labeled as explained previously.

Bulk samples from rotary drilling were obtained by screening the returning drilling fluid to obtain wash samples or collecting soil cuttings returned by compressed air. Recovered samples were placed in plastic bags and labeled as previously explained.

d. Split-Spoon Samples: Split-spoon samplers were used to obtain disturbed, but representative soil samples. The split-spoon sampler consists of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The inside diameter of the sampler shoe is 1.375 inches (35 mm) and the length is about 18 inches (45.7 cm). Sampling with the split barrel sampler is accomplished by driving the sampler into the ground with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm). The number of blows required to drive the sampler a distance of 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value). The disturbed samples obtained from the split-spoon sampler were placed in plastic bags and labeled as explained previously.

A5.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A5.3, "Field Visual Soil Classification," of this Appendix. Rock encountered in the borings was described according to classifications given in Travis (1955) and Folk (1974). The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; and method of drilling and sampling, drill bit type and size, driving weight and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A5.3, "Field Visual Soil Classification," and the description was entered on the logs. Section A5.3 also discusses other pertinent data and observations made, which were entered on the boring logs, during drilling.

A5.1.4 Sample Storage and Transportation

Samples were handled with care, drive spoon sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain so as not to cause any disturbance to the undisturbed samples. Whenever ambient air temperatures fell below 32°F, all samples were stored in heated rooms during the field work and transported to Fugro National's Long Beach laboratory in heated cabins in back of pickup trucks.

A5.2 TRENCHES

A5.2.1 Excavation Equipment

The trenches were excavated using a rubber tire-mounted Case 780 backhoe with a maximum depth capability of 18 feet (5.5 m).

A5.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 to 3 feet (0.6 to 0.9 m). Trench depths were typically 18 feet (5.5 m) and lengths ranged from 54 to 74 feet (16.5 to 22.5 m). The trench walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as practical.

A5.2.3 Sampling

The following sampling procedures were generally followed:

- Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet, bulk samples of both the soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples (weighing about 50 pounds each; 11.4 kg) were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (1 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied

tightly at the top to prevent spillage and tagged with the following information: project number; trench, test pit, or surficial sample number; bulk sample number; depth range in feet; Unified Soil Classification symbol; and date. The samples were transported to the field office for storage and then to Fugro National's Long Beach office in pickup trucks.

A5.2.4 Logging

The procedures for field visual classification of soil and rock encountered from the trenches were basically the same as the procedures for logging of borings (Section A5.1.3). Logging of the trench excavations was accomplished from the surface and by observing the backhoe bucket contents. Most trench walls were photographed prior to backfilling.

Each field trench log included the appropriate number; project name, number and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A5.3, "Field Visual Soil Classification." Section A5.3 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A5.3 FIELD VISUAL SOIL CLASSIFICATION

A5.3.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (see Table A5-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A5.3.2 Soil Description

Soil descriptions entered on the logs of borings, and trenches generally included those listed below.

Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color

Coarse-Grained Soils	Fine-Grained Soils
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HCl	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations follow.

a. USCS Name and Symbol: Derived from Table A5-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 in. (76 mm) in diameter were excluded. Fine-grained soils are those in which more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis with the number 200 sieve (.074 mm) size particle considered to be the smallest size visible to the naked eye. In some instances, the field technicians describing the soils used a number 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the number 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (See ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. Color: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. Range in Particle Size: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. Gradation: Well graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. Density or Consistency: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease (or difficulty) of excavation of trench or test pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented [illegible] were also used to estimate consistency.

- Coarse-grained soils - GW, GP, GM, GC, SW, SP, [illegible] (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

- Fine-grained Soils - ML, MH, CL, CH (Silts and Clays)

Consistency	Shear Strength (ksf)	Field Guide
Very Soft	<0.25	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	Can be squeezed between thumb and forefinger

Consistency	Shear Strength (ksf)	Field Guide
Firm	0.50-1.00	Can be molded easily with fingers
Stiff	1.00-2.00	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	Can be imprinted with considerable pressure from fingers
Hard	Over 4.00	Cannot be imprinted by fingers

f. Moisture Content- The following guidelines were used in the field for describing the moisture in the soil samples:

Dry	-	No feel of moisture
Slightly Moist	-	Much less than normal moisture
Moist	-	Normal moisture for soil
Very Moist	-	Much greater than normal moisture
Wet	-	At or near saturation

g. Particle Shape- Coarse-grained soils

Angular	-	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	-	Particles are similar to angular but have somewhat rounded edges
Subrounded	-	Particles exhibit nearly plane sides but have well-rounded corners and edges
Rounded	-	Particles have smoothly curved sides and no edges

h. Reaction to HCl- As an aid for identifying cementation, some soil samples were tested in the field for their reaction to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. Degree of Cementation- Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments

(Contd.)

Stage	Gravelly Soils	Nongravelly Soils
III	Many intergravel fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

3. Secondary Material - Example: Sand with trace to some silt

Trace	1-10% (by dry weight)
Little	11-20% (by dry weight)
Some	>20% (by dry weight)

4. Cobbles and Boulders - A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling and difficulty of cutting in borings or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

5. Depth of Change in Soil Type - During drilling of borings, the depth of changes in soil type was determined by observing samples, drilling rates, changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A5.4 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Fugro National's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California and Smith-Emery Company of Los Angeles, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A6.9 DATA ANALYSIS AND INTERPRETATION

A6.9.1 Preparation of Final Logs and Laboratory Test Summary Sheets

The final logs of all borings and trenches were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs include generally the following information: description of soil types encountered; sample types or intervals, lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic unit, date of activity, equipment used, and dimensions of the activity are shown on the log.

Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in-situ dry strength and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

[illegible]

Boring Logs	Section II - 4.0
Trench Logs	Section II - 5.0
Laboratory Test Results	Section II - 6.0

.5.2 Soil Characteristics

aracteristics of the subsurface soils were developed using ta from seismic refraction surveys, borings, trenches, and boratory tests.

he soils were divided into coarse-grained and fine-grained oils in two ranges of depth, 0 to 20 feet and 20 to 160 feet 0 to 6 m and 6 to 49 m). Physical and engineering properties f the soils were then tabulated as "Characteristics of Subsurface Soils" (Table 3-1) based on laboratory test results on epresentative samples. The table includes soil descriptions, nified Soil Classification System symbols, the estimated ubsurface extent of each soil group, comments on the degree of ementation, estimated cobbles content, and ranges of values rom the following laboratory tests: dry density, moisture ontent, grain-size distribution, liquid limit, plasticity ndex, unconfined compression, triaxial compression, and direct hear.

he excavatability and stability of excavation walls of a orizontal or a vertical shelter were evaluated from the subsurface data using seismic velocities, soil types, shear strength, resence of cobbles and boulders, and cementation. Problems ncountered during trench excavations and drilling of borings ere also considered in the evaluation.

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